ABI Fire Products

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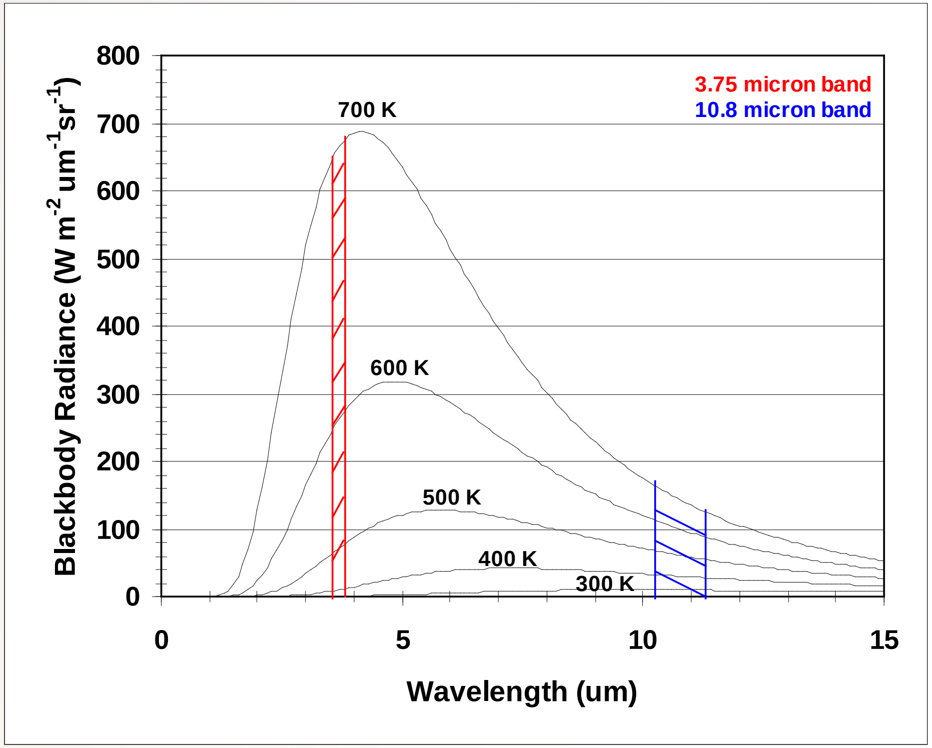
GOES-16 Fire Detection and Characterization Algorithm

- Geostationary fire detection and characterization has been available 24/7 since 2002 when the Wildfire Automated Biomass Burning Algorithm (WFABBA) was made an operational product by NOAA/NESDIS
- The WFABBA produces fire location and characterization data for all data received from current GOES, Meteosat Second Generation, COMS, the formerly operational MTSAT series, and the Advanced Himawari Imager (AHI) on Himawari-8
- The experience with current generation geostationary platforms informed the requirements for the Advanced Baseline Imager (ABI) on GOES-R, and the WFABBA was adapted to the instrument and is a baseline product (under the name **Fire Detection and Characterization Algorithm** [FDCA])
- The WFABBA's legacy as an algorithm for multiple instruments allows for excellent continuity as we transition to the new generation of geostationary imagers represented by ABI and AHI
- The FDCA produces **fire size**, **fire temperature**, **fire radiative power (FRP)**, and a **mask** that gives 6 fire categories and information about the other, non-fire pixels
- It is produced for CONUS and Full Disk scans only (if you would like to see Meso scans supported, make sure the right people know)

How Does Fire Detection and Characterization Work?

- Almost all fire algorithms use at least 2 IR bands: ~4 µm and ~11 µm. The FDCA also uses the 0.64 µm and 12.3 µm bands for cloud screening.
- Fire characterization requires some additional information data (amount of water in the atmosphere, the surface composition).
- The algorithm is contextual to best handle estimating what the surface looks like without a fire – we need to know that if we want to estimate the intensity of the fire.
- Fires are always smaller than a GOES pixel, so there are limits to how well we can characterize them. Diffraction of the infrared light into the detector and uncertainty in the satellite navigation are the biggest factors.
- Remapping can distort fire data, and has been observed for ABI, Himawari-8 AHI, Meteosat-8/-9/-10, and COMS-1.

Fire Detection and Characterization



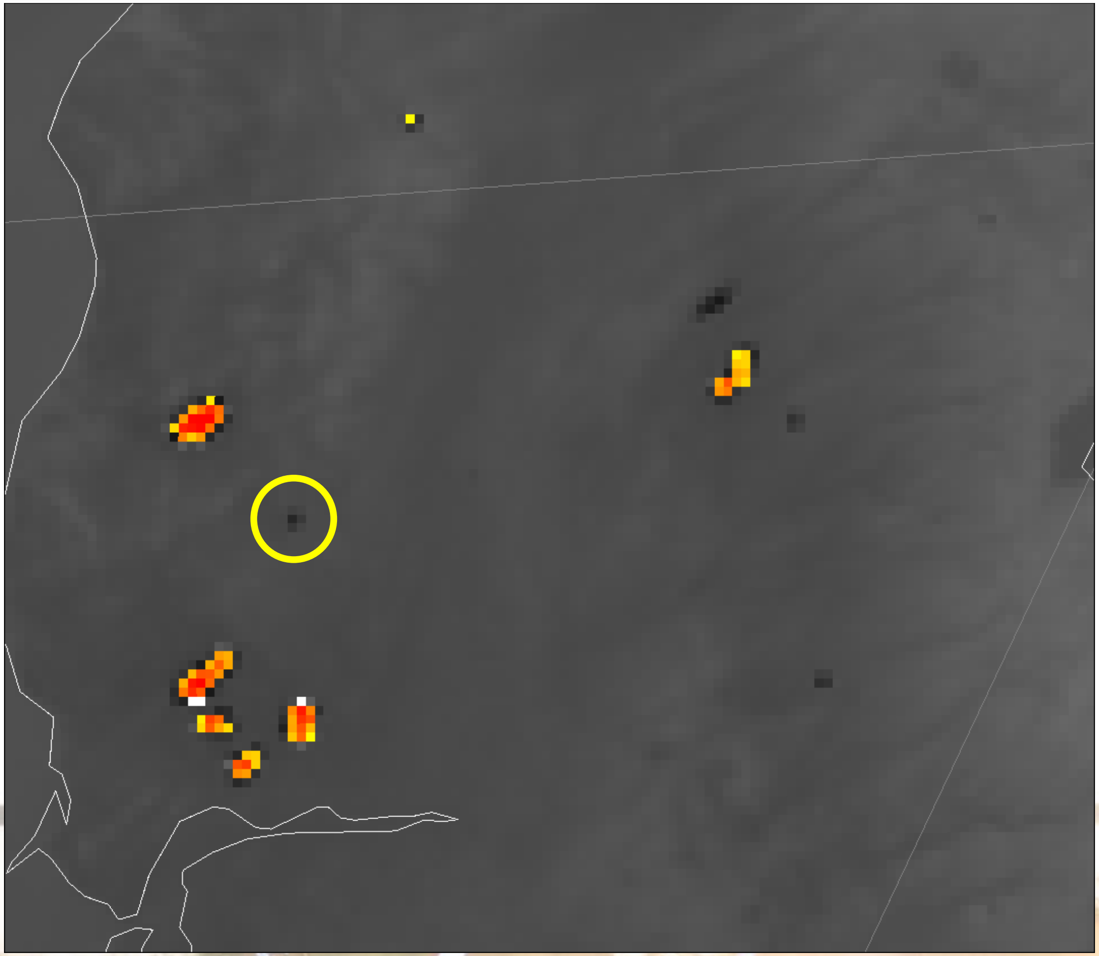
As the surface temperature increases, the peak of the Planck function shifts toward shorter wavelengths, so the radiance increases more rapidly at ~4 µm than ~11 µm. The different brightness temperature responses in these two infrared windows and background conditions can be used to detect fires and estimate sub-pixel fire size, temperature and fire radiative power (FRP).

The Planck function: Describes emitted energy at a given temperature and wavelength.
Radiance: A measure of the emitted energy.
Brightness Temperature: The temperature sensed by the detector, it is wavelength dependent and not the same as the bulk temperature of the surface or fire.

Fire Detection and Characterization

9 October 2017, 8:37:22 UTC

What follows is a quick tour through the bands and whether they can see fires. This is band 7, 3.9 µm, the "fire" band. The yellow circle highlights a cooler and/or smaller fire. The red indicated the hottest fires.



Fire Detection and Characterization

9 October 2017, 8:37:22 UTC

Band 1, 0.47 µm

The “blue” band – no fire signal is visible for even the hottest fires.

Fire Detection and Characterization

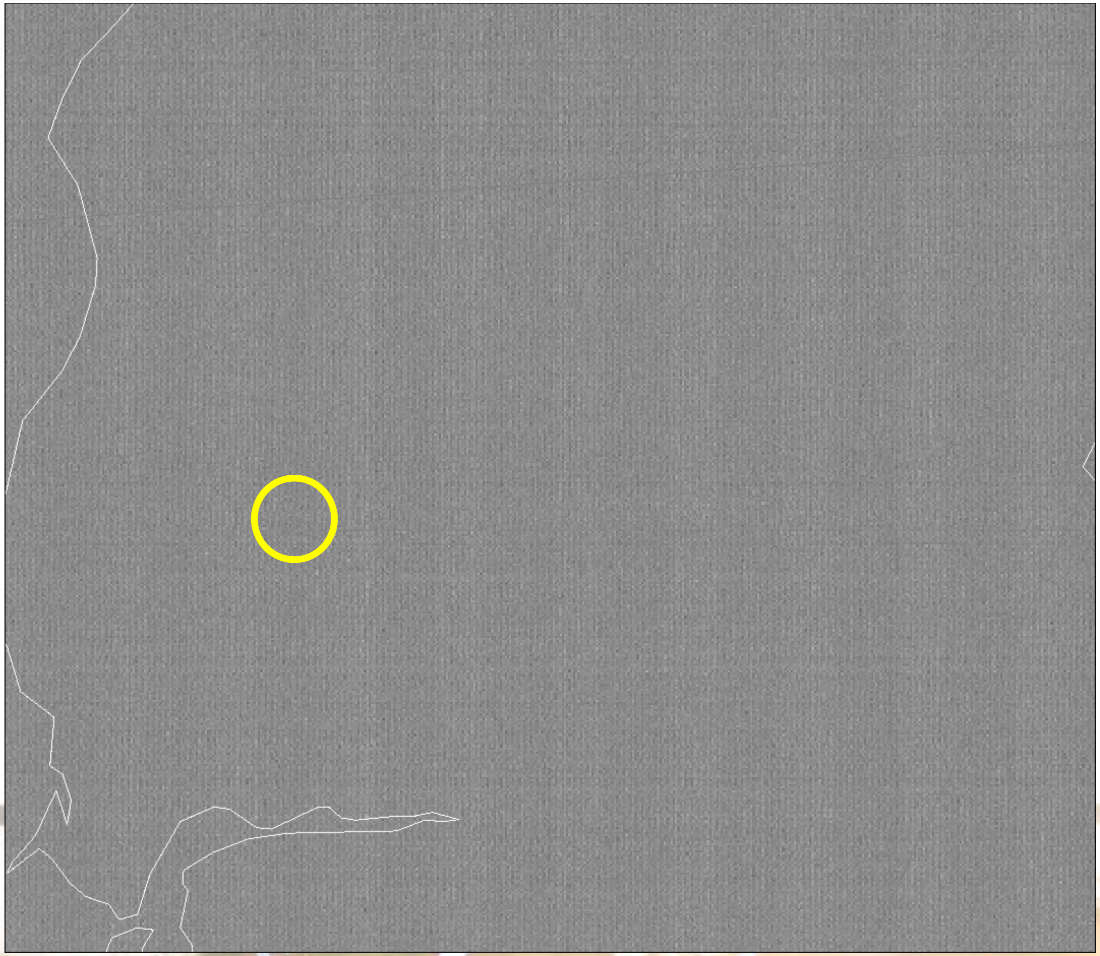
9 October 2017, 8:37:22 UTC

Band 2, 0.64 µm

The “red” band – no fire signal is visible for even the hottest fires.

Stretched -0.012 to 0.01 albedo* with a gamma of 2 to highlight the lack of signal. The pattern is from detector biases and the remapper combined.

* Since it is nighttime we are looking for emissions



Fire Detection and Characterization

9 October 2017, 8:37:22 UTC

Band 3, 0.86 µm

The “veggie” band – some fire signal is visible.

Fire Detection and Characterization

9 October 2017, 8:37:22 UTC

Band 4, 1.38 µm

The "cirrus" band – the surface is obscured by absorption and there is no sunlight to reflect. Fire signal visible in some cases.

Stretched -0.012 to 0.02 albedo with a gamma of 1.9.

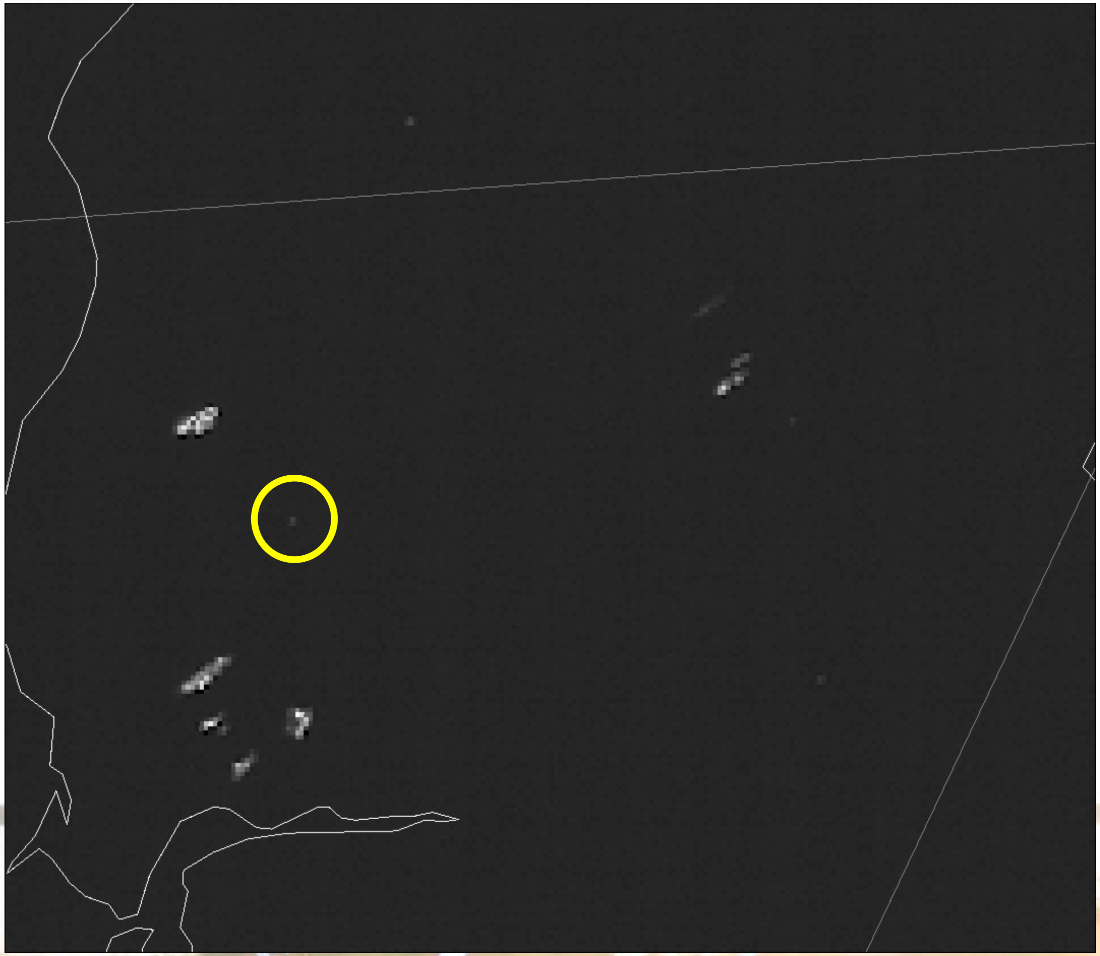
Fire Detection and Characterization

9 October 2017, 8:37:22 UTC

Band 5, 1.6 μm

The “snow/ice” band – cooler fires are starting to appear.

Stretched -0.012 to 0.602 albedo with a gamma of 0.6.



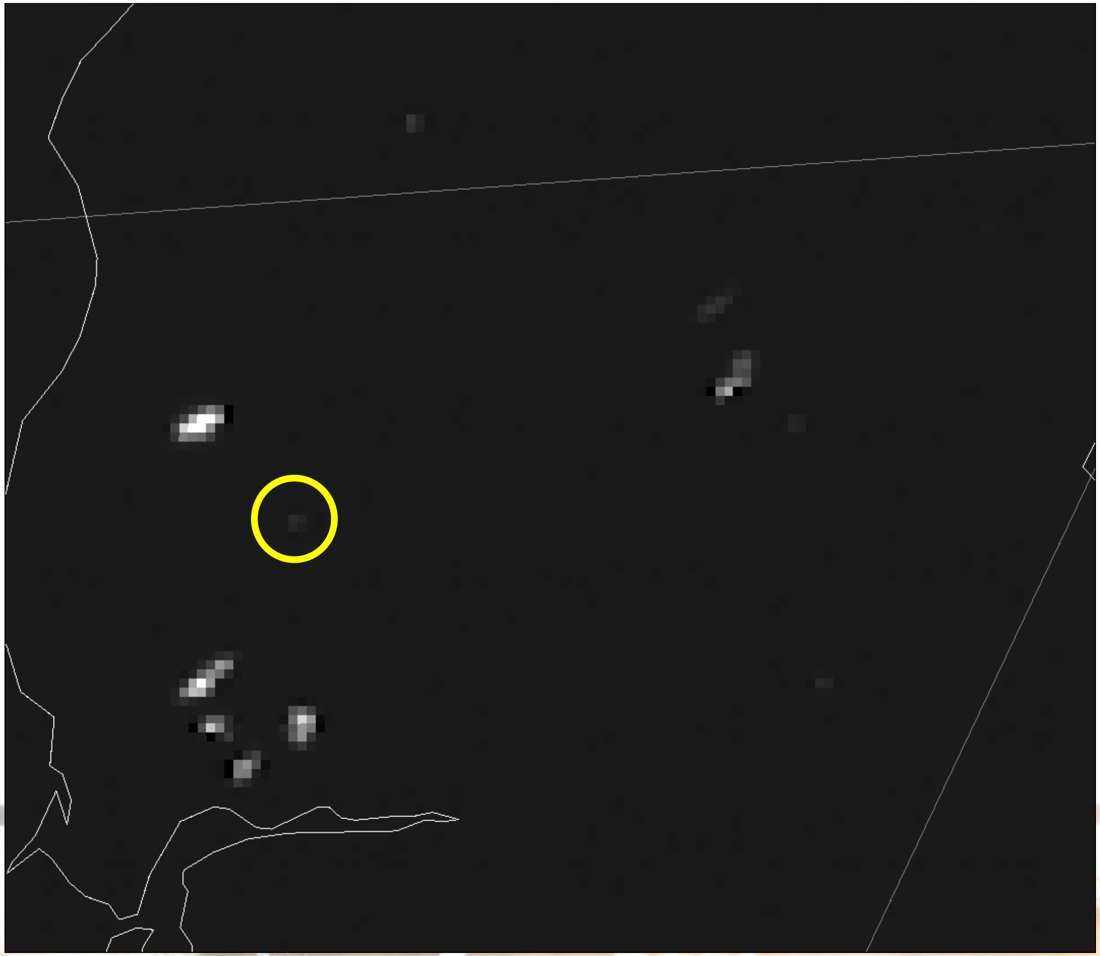
Fire Detection and Characterization

9 October 2017, 8:37:22 UTC

Band 6, 2.25 µm

The “cloud particle size” band – similar to band 5 but smaller fires are harder to see due to lower resolution.

Stretched -0.012 to 1.192 albedo with a gamma of 1.



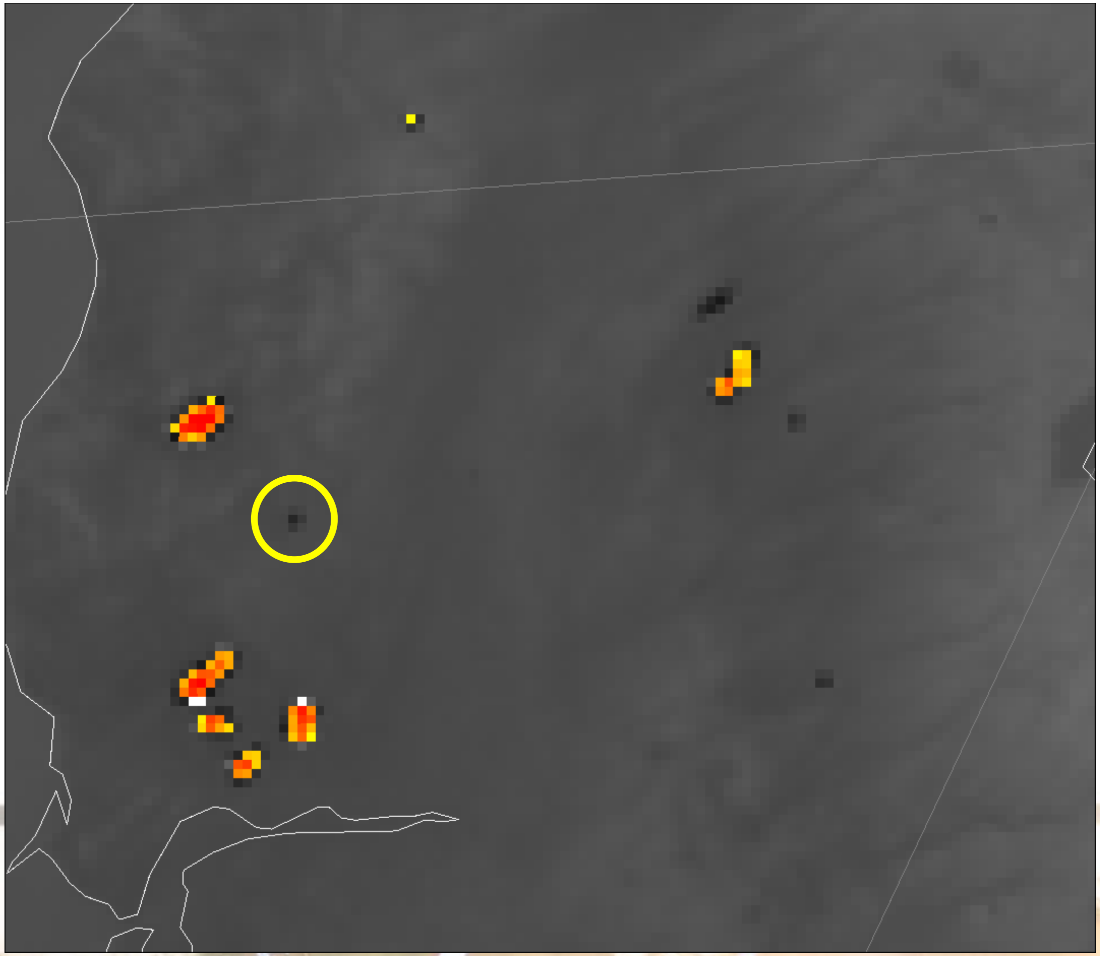
Fire Detection and Characterization

9 October 2017, 8:37:22 UTC

Band 7, 3.9 μm

The “fire” band – most sensitive to fires.

Stretched 164K to 413K, gamma=1.
(sensor saturation is ~411K)



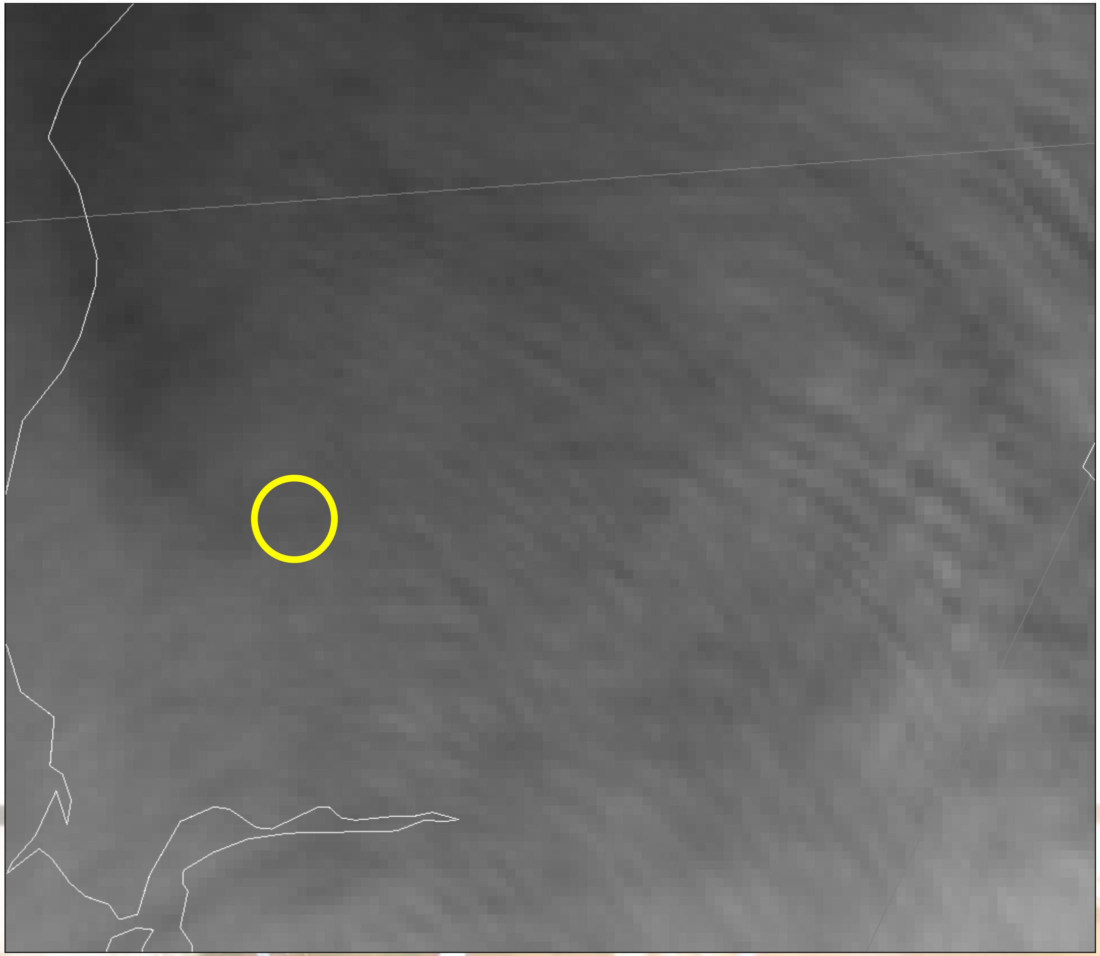
Fire Detection and Characterization

9 October 2017, 8:37:22 UTC

Band 8, 6.2 µm

The "upper level tropospheric water vapor" band. No fire signals in this example (they may be visible when the column is extremely dry).

Stretched 228K to 246K, gamma 1.5.



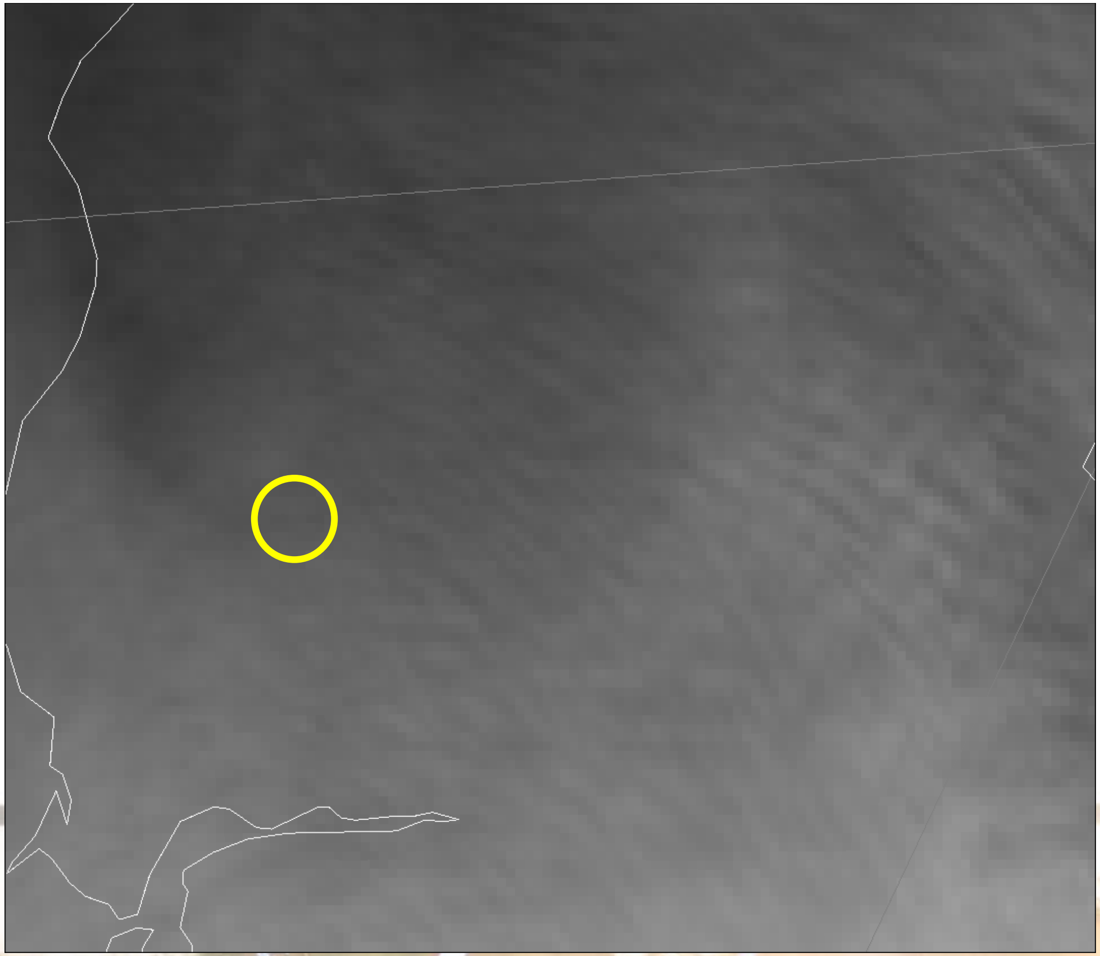
Fire Detection and Characterization

9 October 2017, 8:37:22 UTC

Band 9, 6.9 μm

The "mid level tropospheric water vapor" band – no fire signal.

Stretched 241K to 259K, gamma=1.2.



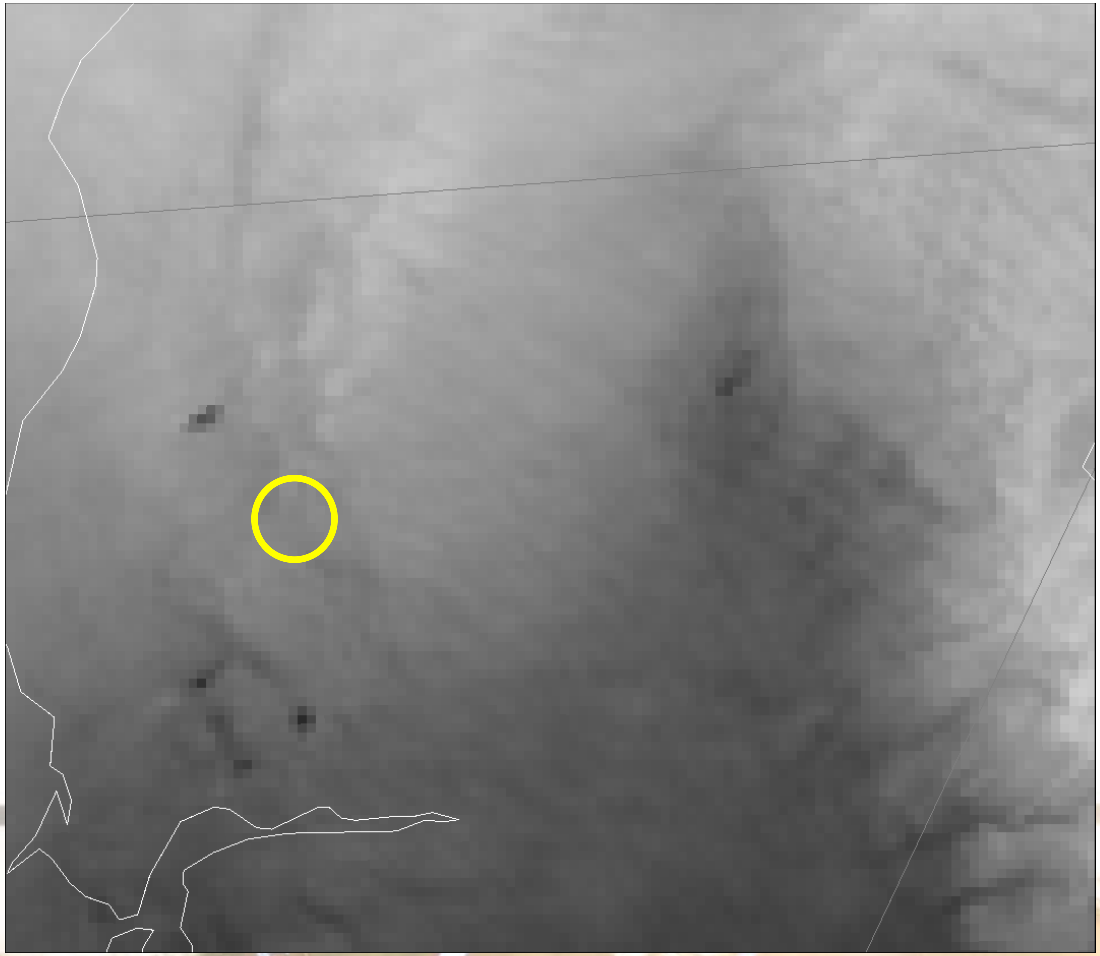
Fire Detection and Characterization

9 October 2017, 8:37:22 UTC

Band 10, 7.3 μm

The “low level tropospheric water vapor” band. Fire signals start to appear.

Stretched 244K to 267K, gamma=1.2.



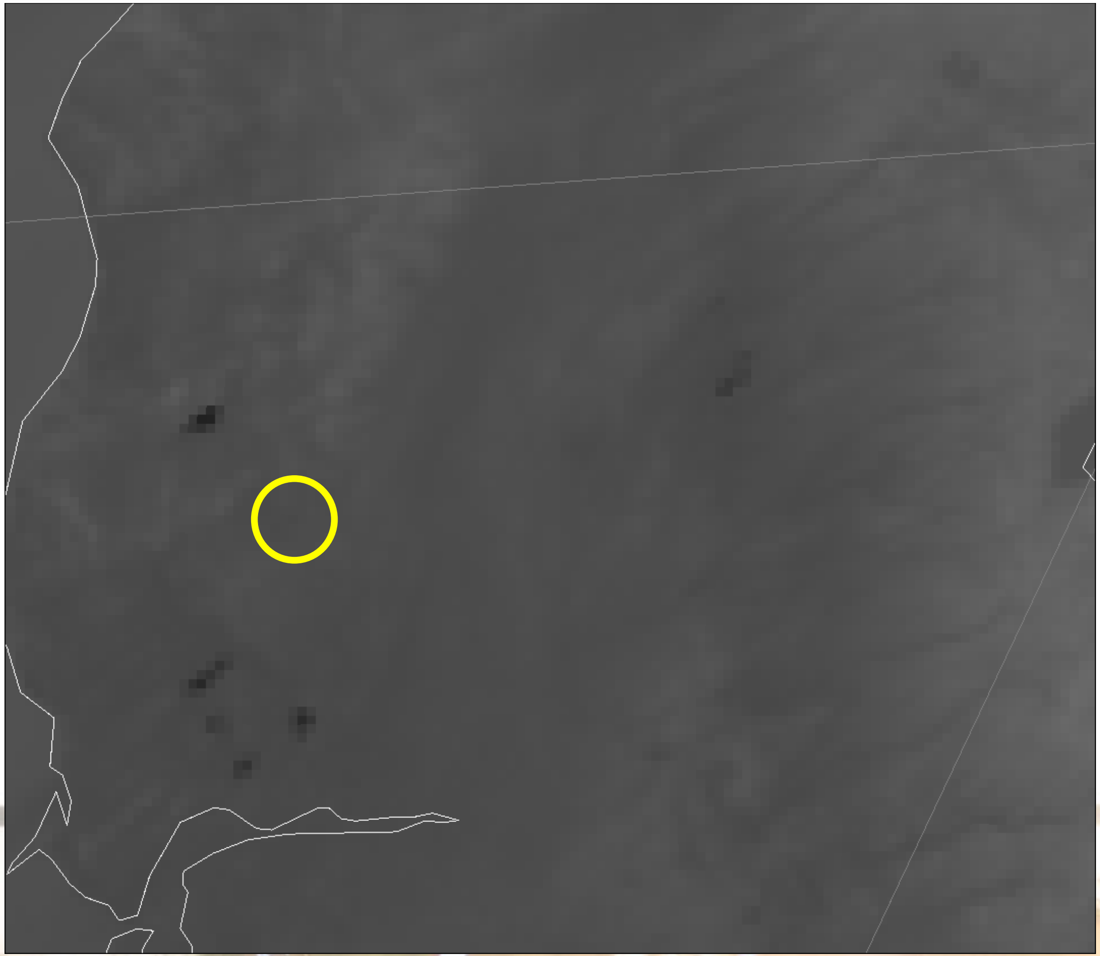
Fire Detection and Characterization

9 October 2017, 8:37:22 UTC

Band 11, 8.4 µm

The "cloud top phase" band – an IR window band, some fires show up.

Stretched 164K to 413K, gamma=1.



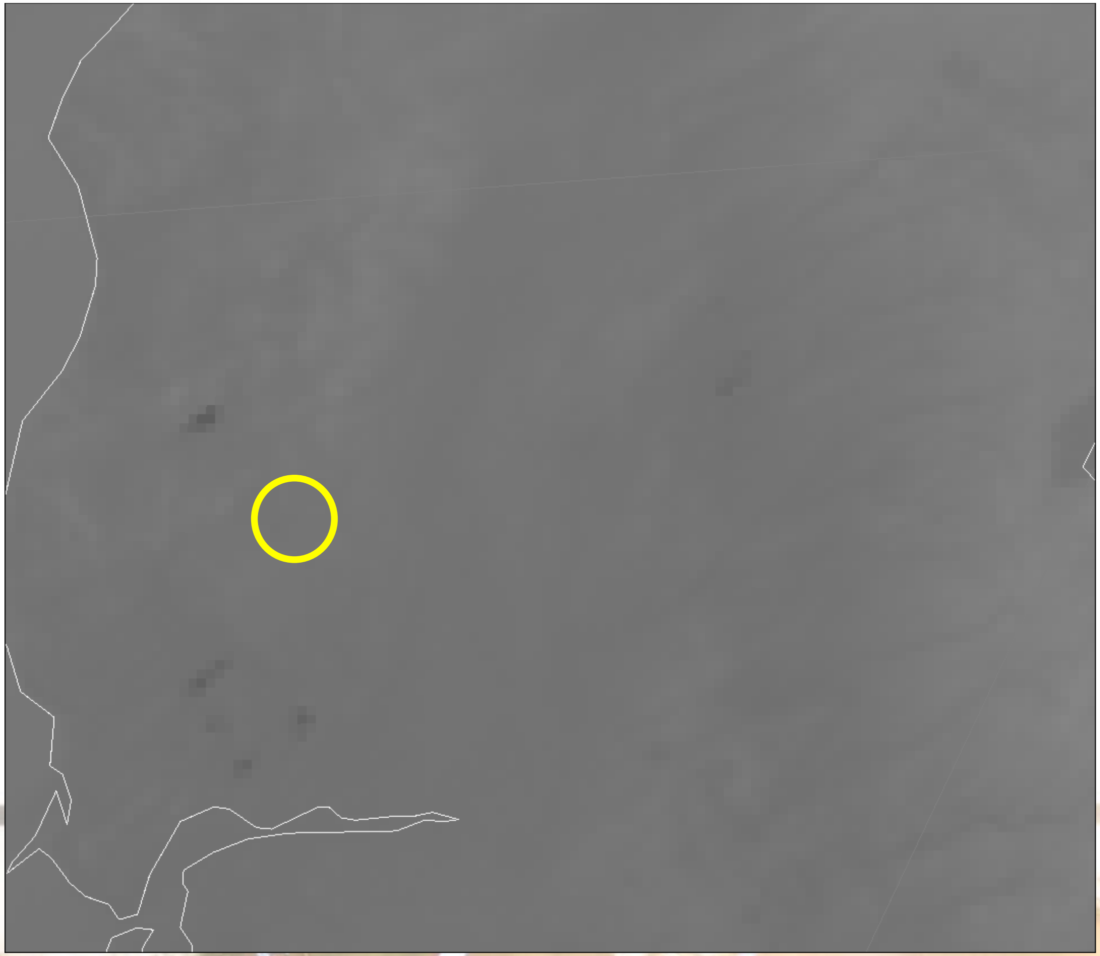
Fire Detection and Characterization

9 October 2017, 8:37:22 UTC

Band 12, 9.6 µm

The “ozone” band – ozone attenuation dims the fires but some still shine through.

Stretched 164K to 413K, gamma=1.



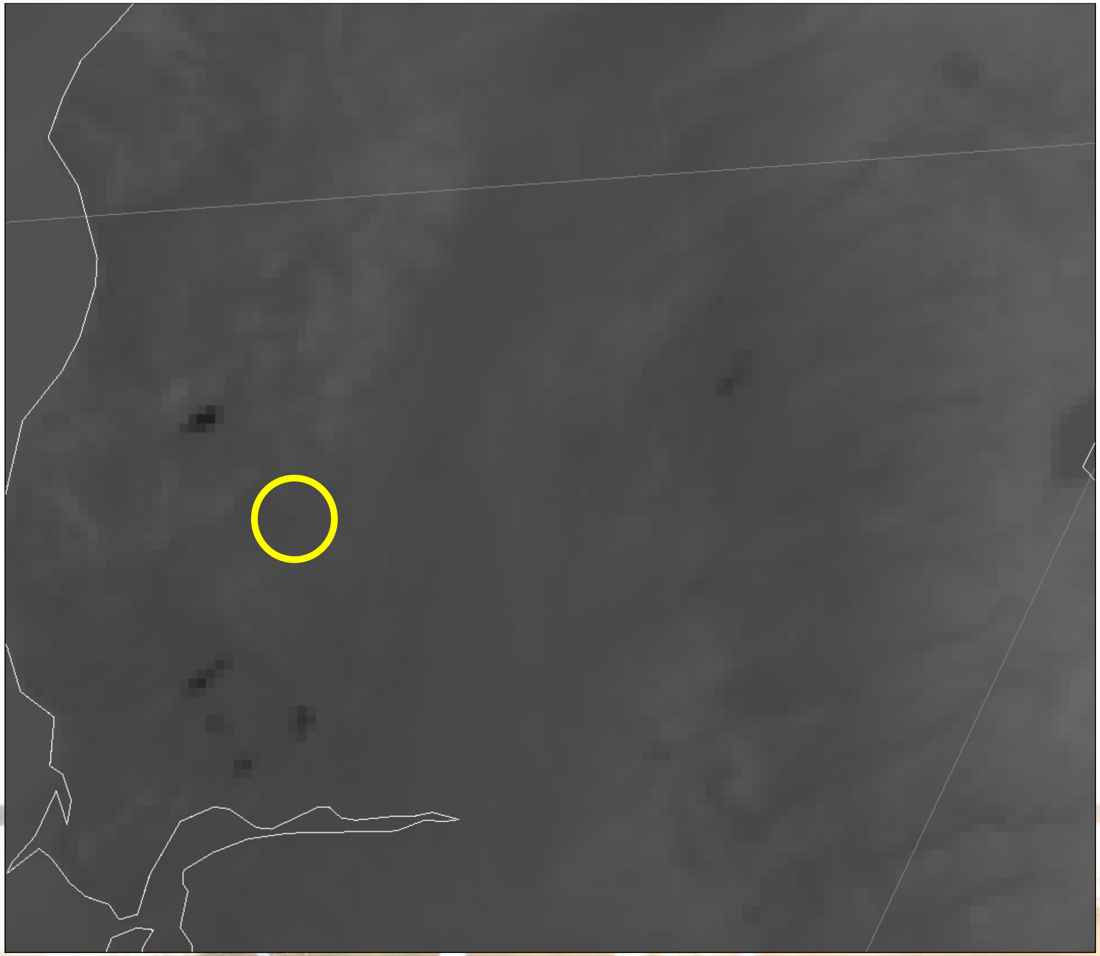
Fire Detection and Characterization

9 October 2017, 8:37:22 UTC

Band 13, 10.3 μm

The “clean IR window” band – hotter/larger fires show through.

Stretched 164K to 413K, gamma=1.



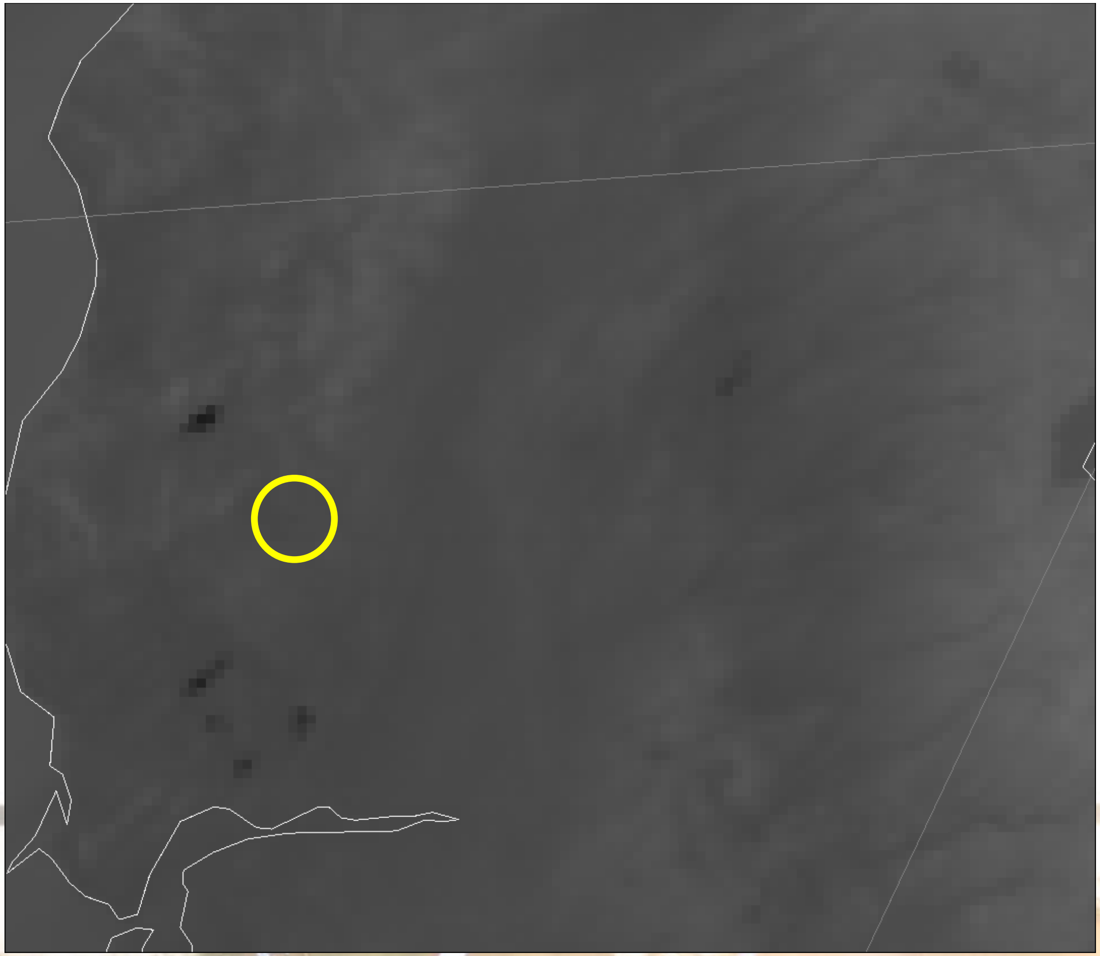
Fire Detection and Characterization

9 October 2017, 8:37:22 UTC

Band 14, 11.2 μm

The “IR longwave window” band – this is the traditional band used for comparing to band 7 in fire algorithms.

Stretched 164K to 413K, gamma=1.



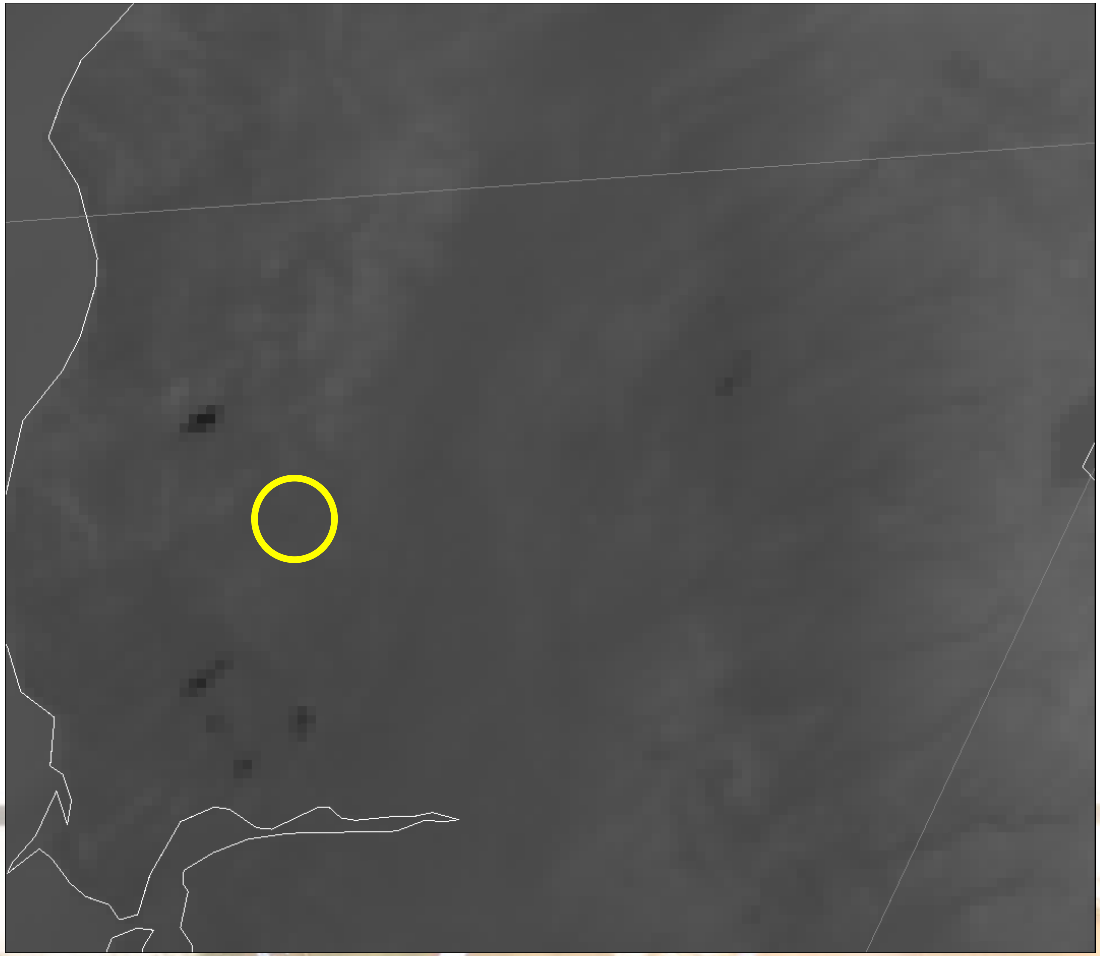
Fire Detection and Characterization

9 October 2017, 8:37:22 UTC

Band 15, 12.3 µm

The “dirty window” band – a bit more water vapor attenuation. Used by the algorithm for cloud screening.

Stretched 164K to 413K, gamma=1.



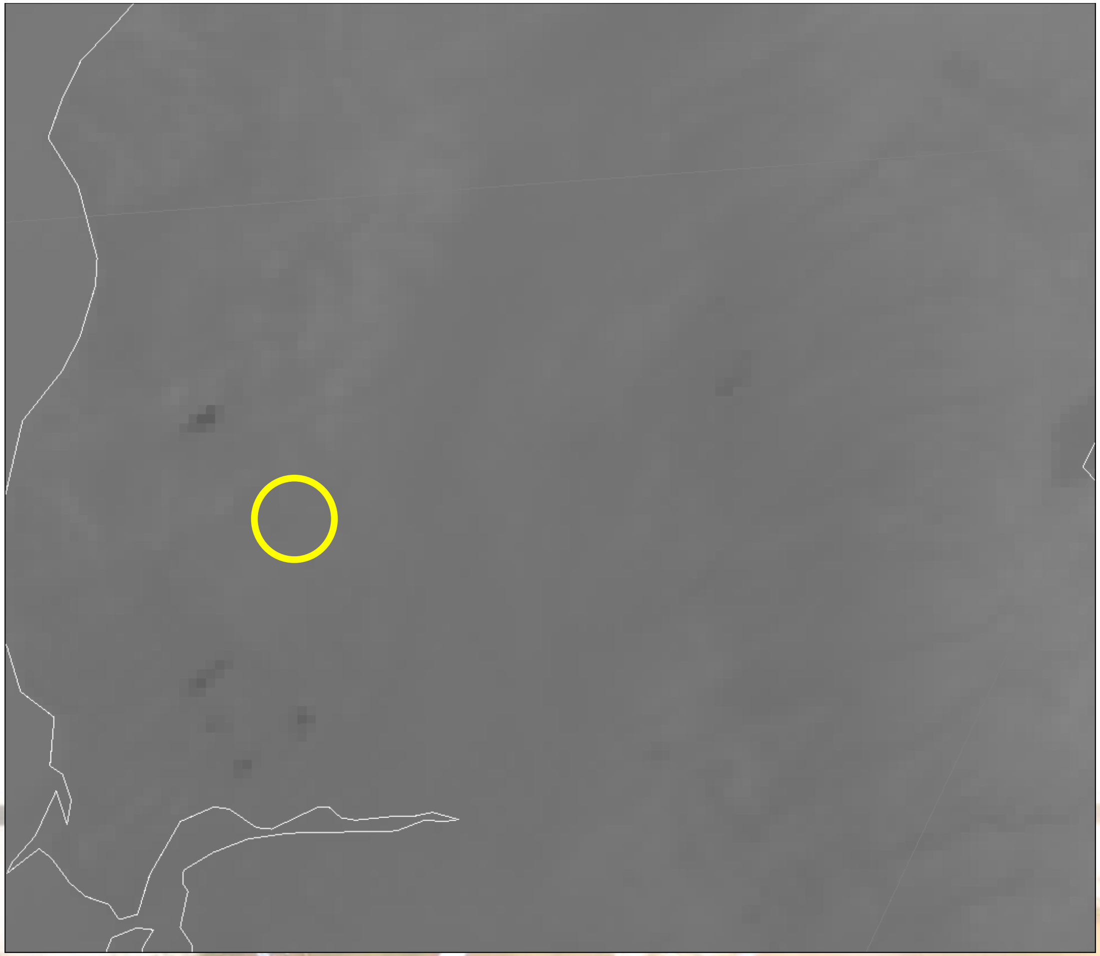
Fire Detection and Characterization

9 October 2017, 8:37:22 UTC

Band 16, 13.3 µm

The "CO_2" band – much like the ozone band, fire signals still present but attenuated.

Stretched 164K to 413K, gamma=1.



Fire Detection and Characterization

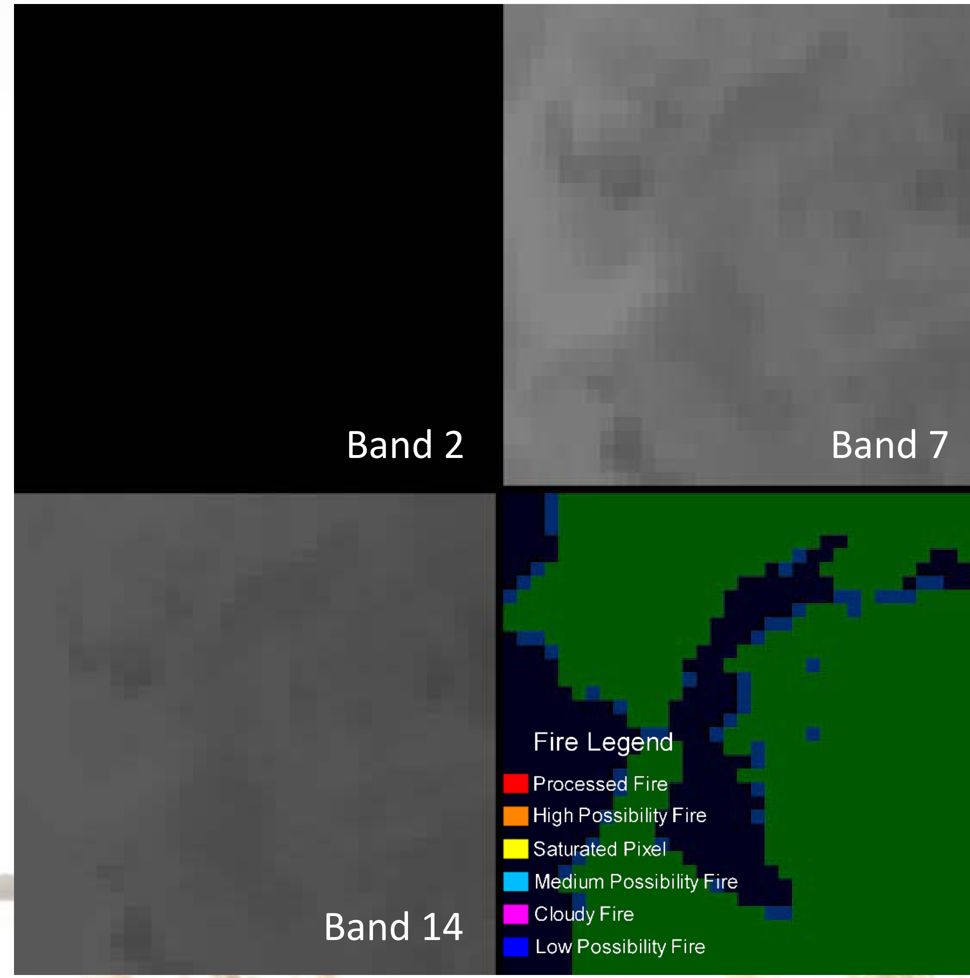
The bands and the detections

Oakland, CA, 7 July 2017 (2017188) between 11 and 14 UTC

Apartment project under construction burned in the early morning hours (note nothing in band 2 until the very end)

This is a unique case given the very limited extent of the fire.

Band 14 barely changes (it *is* looping!), fire clearly visible in band 7 (darker is hotter). Despite small size of fire, it occupies 4 pixels at peak. This is due to the remapping of ABI data.



The Tubbs Fire

Recorded start time: 9:45 PDT on October 8, 2017

The Tubbs Fire was one of the most destructive wildfires in California history, burning parts of Napa, Sonoma, and Lake counties in Northern California during October 2017. By the time it was over on October 31, 2017, it had burned nearly 37,000 acres and killed at least 22 people and untold numbers of animals. More than 2,800 buildings were destroyed in Santa Rosa alone, including the home of the widow of Charles Schulz.

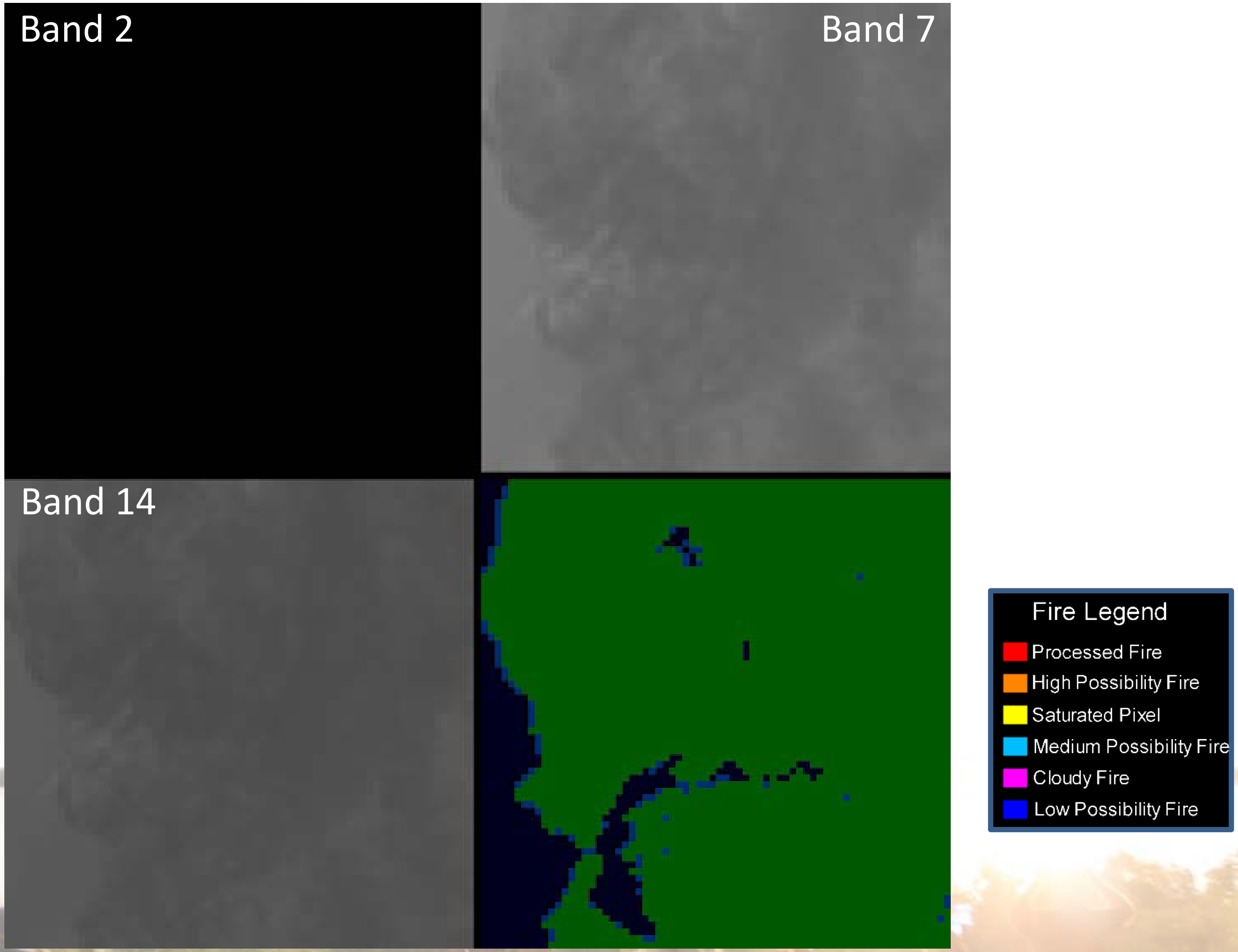
The first alert of the fire at the Bay Area NWS came from the GOES-16 ABI fire product, which detected it on the 4:47 UTC (9:47 PDT) scan.

This fire underwent very rapid intensification.

The Tubbs Fire

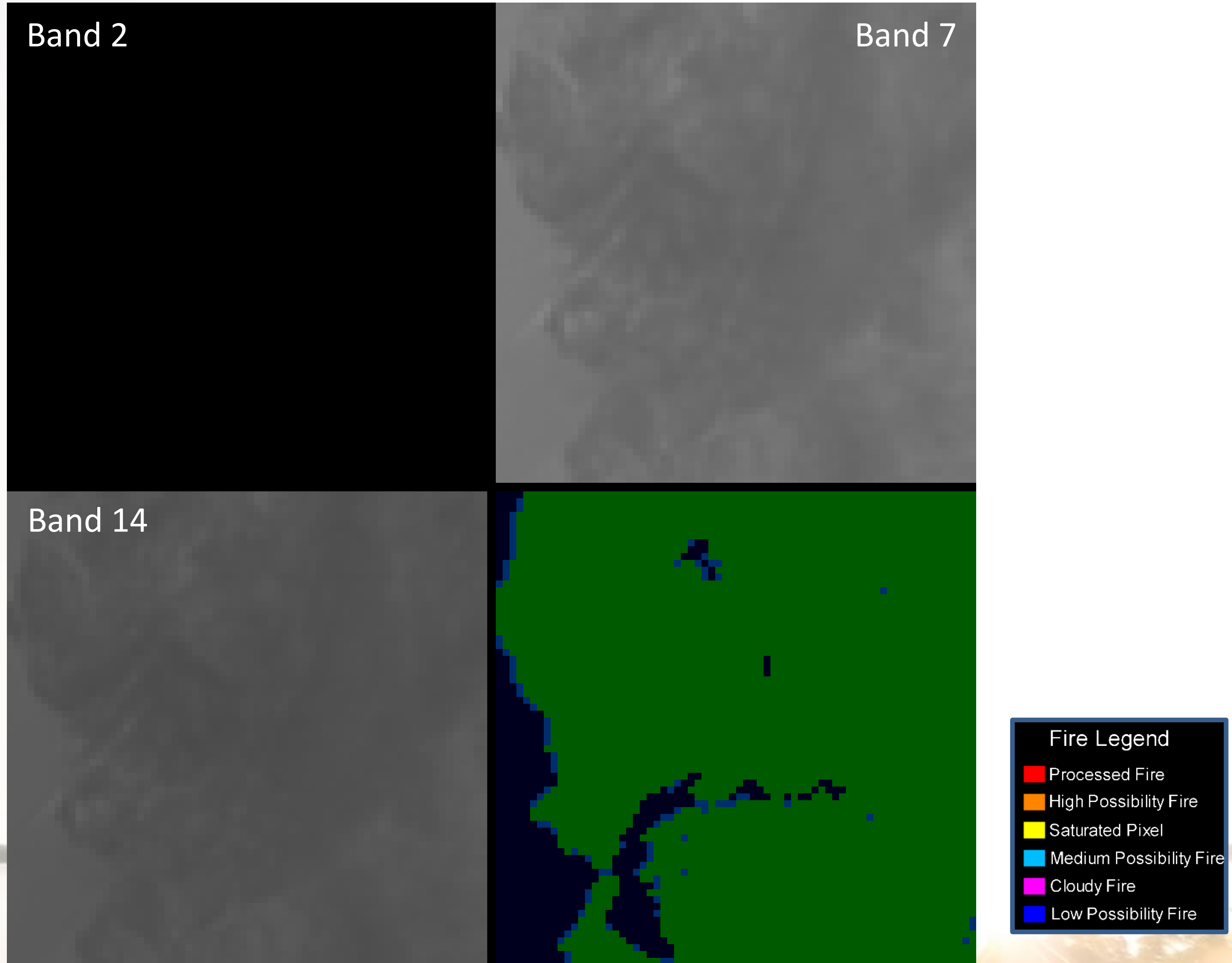
Recorded start time: 9:45 PDT on October 8, 2017

Loop is from 8:07 PDT to 18:07 PDT (3:07 – 13:37 UTC)



The Tubbs Fire

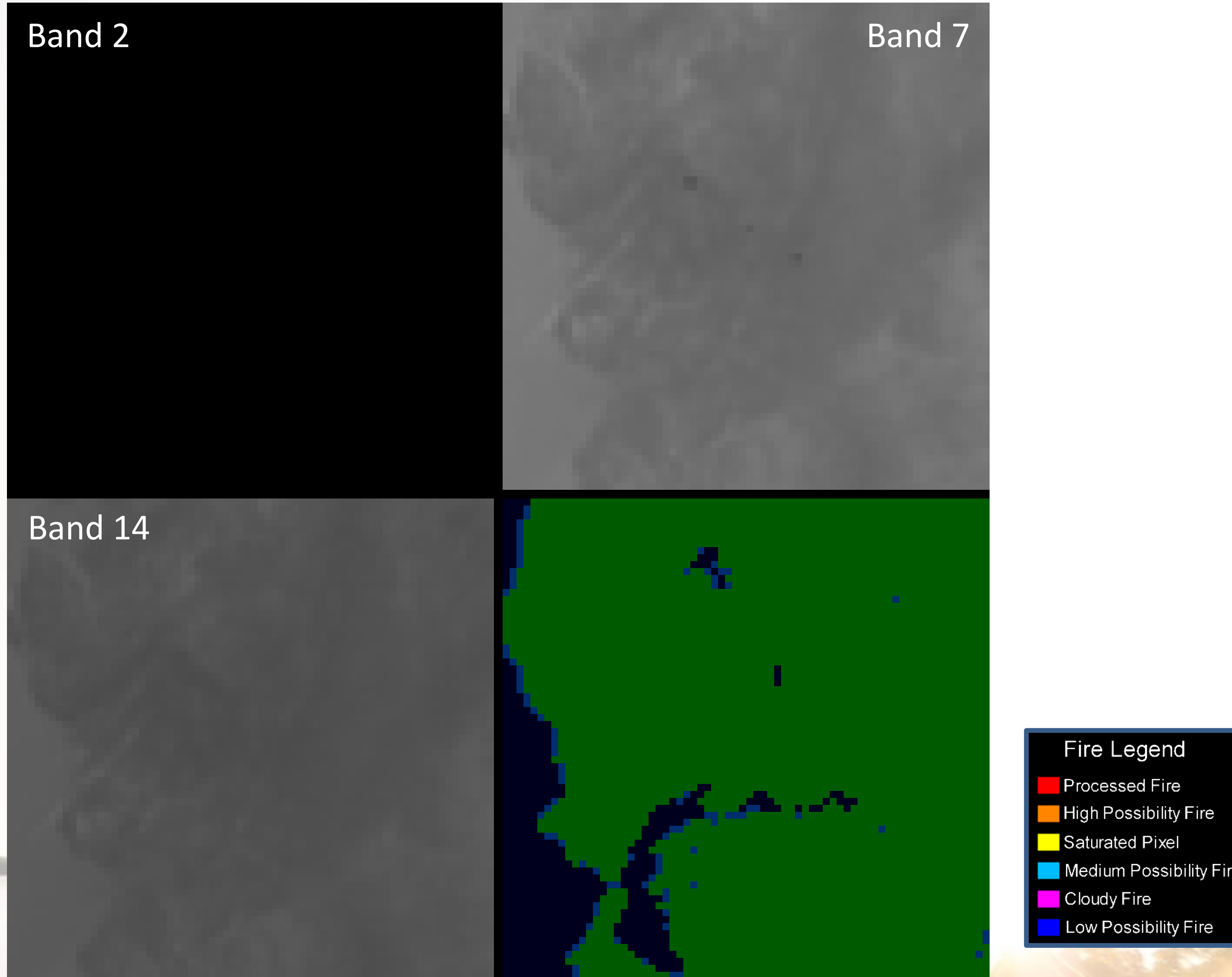
9:37 PDT
(4:37 UTC)
October 8,
2017



The Tubbs Fire

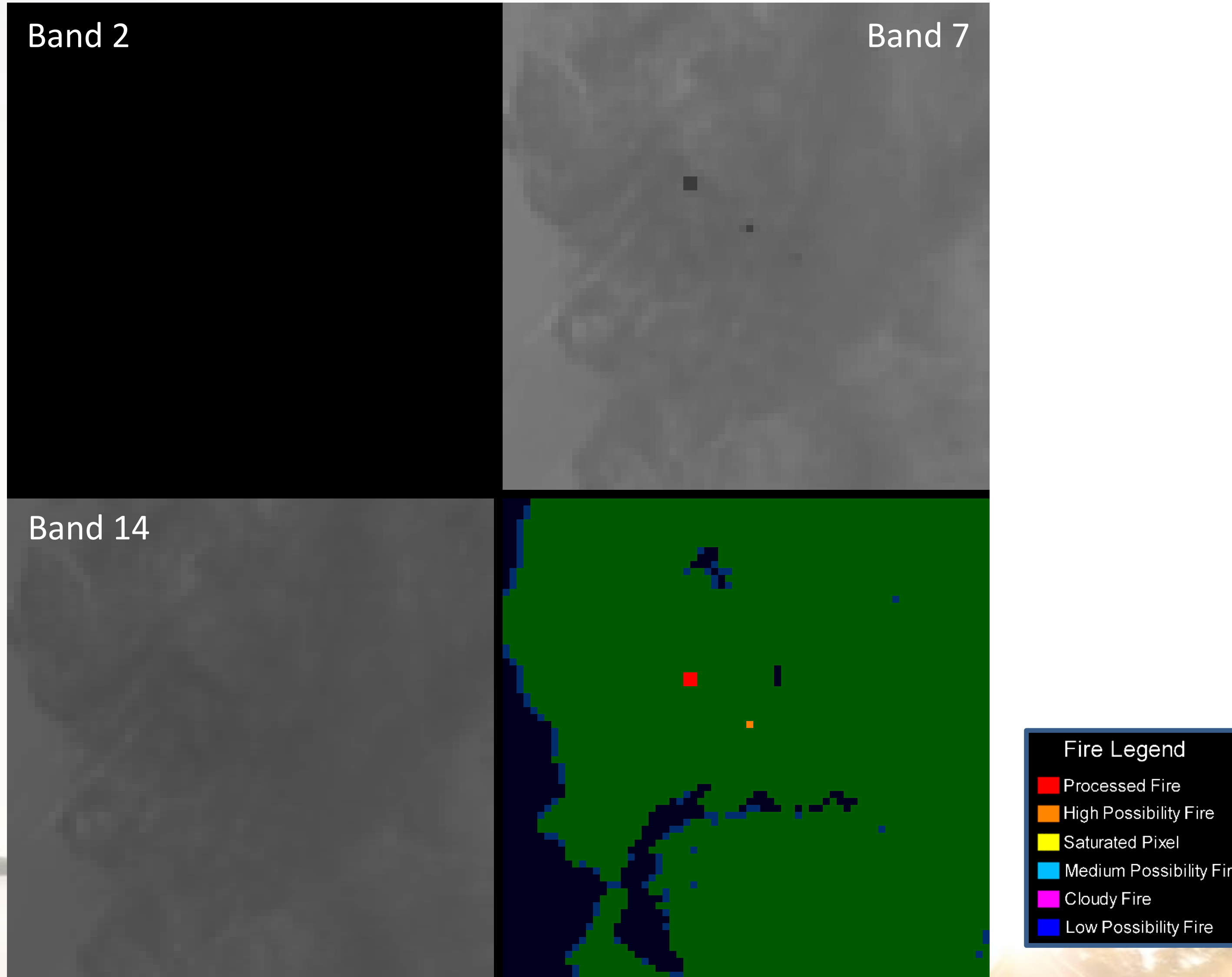
9:42 PDT
(4:42 UTC)
October 8, 2017

Warm pixels visible but under the minimum required threshold difference



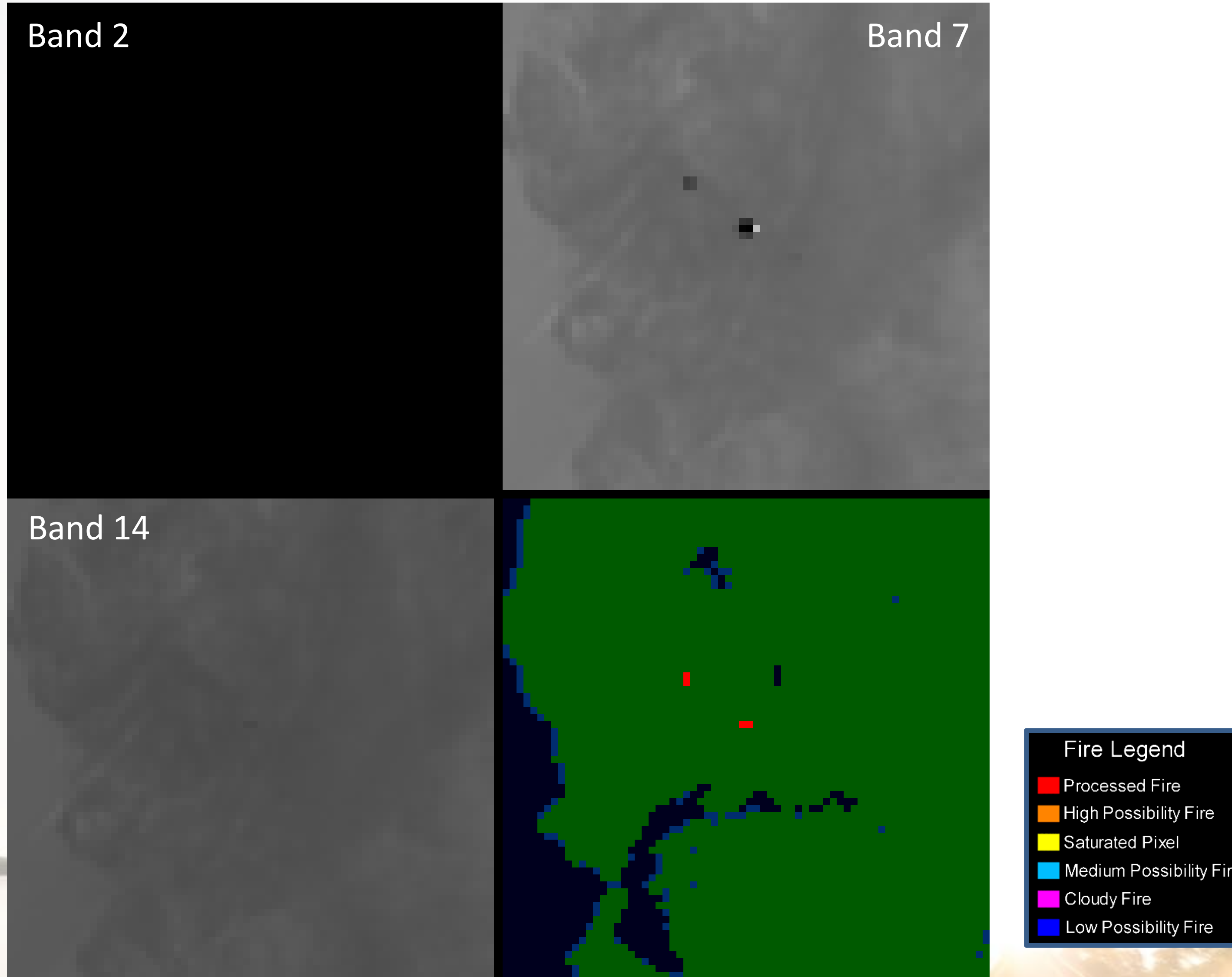
The Tubbs Fire

9:47 PDT
(4:47 UTC)
October 8, 2017



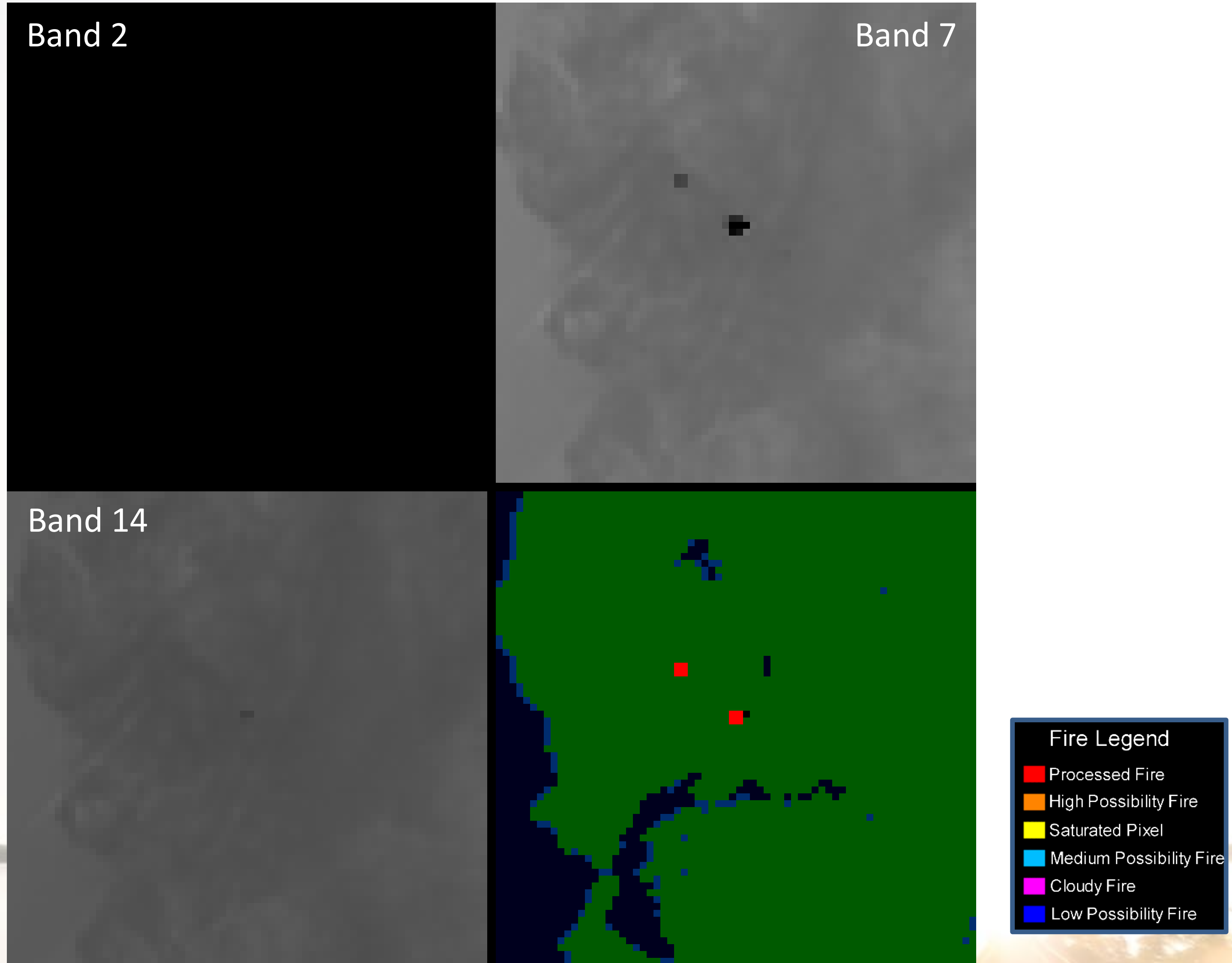
The Tubbs Fire

9:52 PDT
(4:52 UTC)
October 8,
2017



The Tubbs Fire

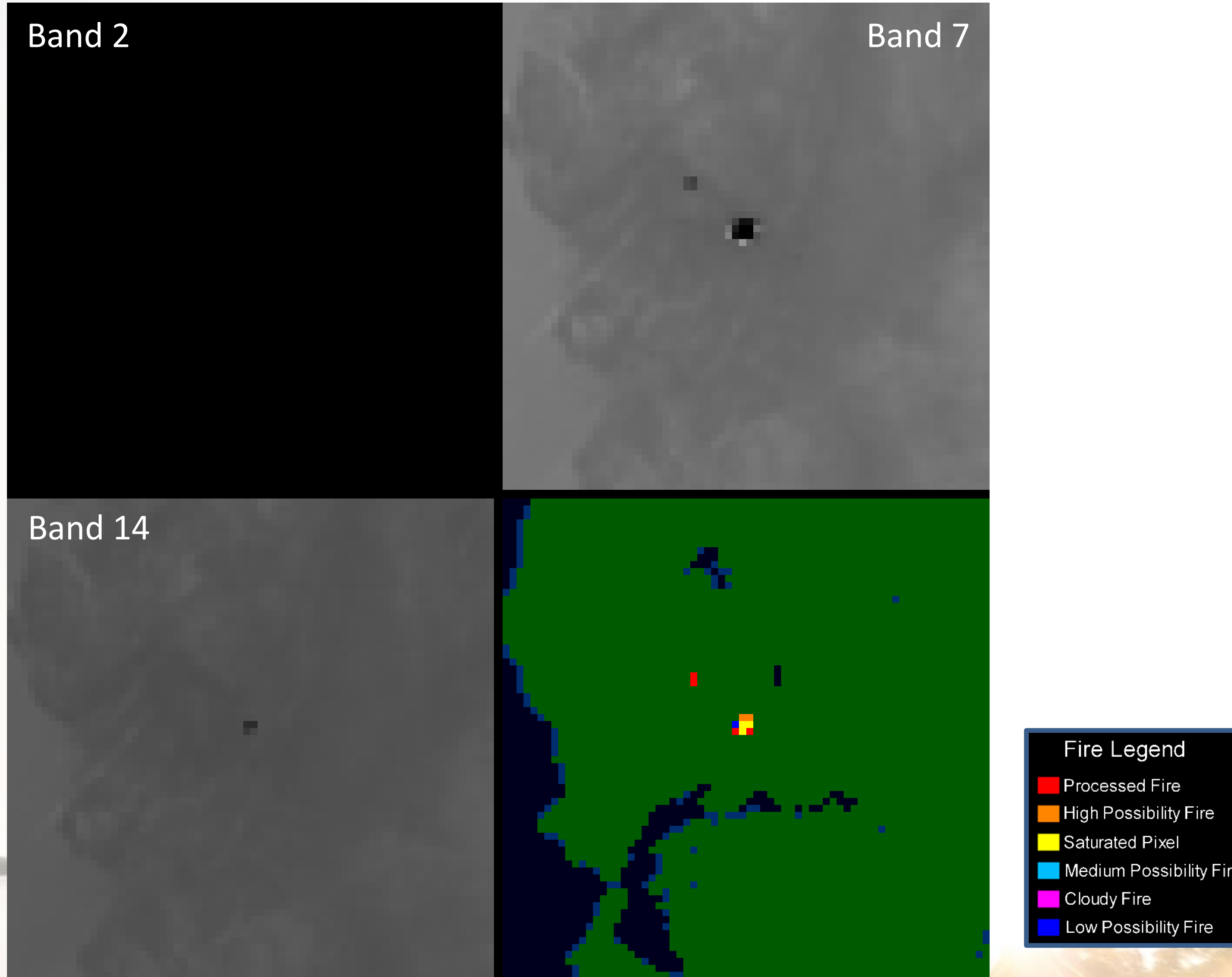
9:57 PDT
(4:57 UTC)
October 8,
2017



The Tubbs Fire

10:02 PDT
(5:02 UTC)
October 8,
2017

Within 20 minutes of first being visible, the fire has grown markedly and saturated the sensor



The Tubbs Fire

The Bay Area NWS first noted the Tubbs fire in the L2 fire temperature product as displayed in AWIPS at 4:52 UTC when a pixel happened to fall into the range of 600-1200 K in that product. (Fire temperature is not the same as band 7 brightness temperature) It had been detected by the algorithm 5 minutes earlier but since it was not a processed fire and lacked temperature, size, and FRP, NWS could not see it due to the configuration of their display system. (This situation is being remedied)

Manitoba and Saskatchewan: 20 May 2018

ABI-class sensors and the FDCA are able to detect a wide-range of fires. This example from a relatively cloud-free spring day in Manitoba, Saskatchewan, and the north central US captures, at the least, large forest fires, likely gas flares from oil operations, and agricultural burning.

Manitoba and Saskatchewan: 20 May 2018

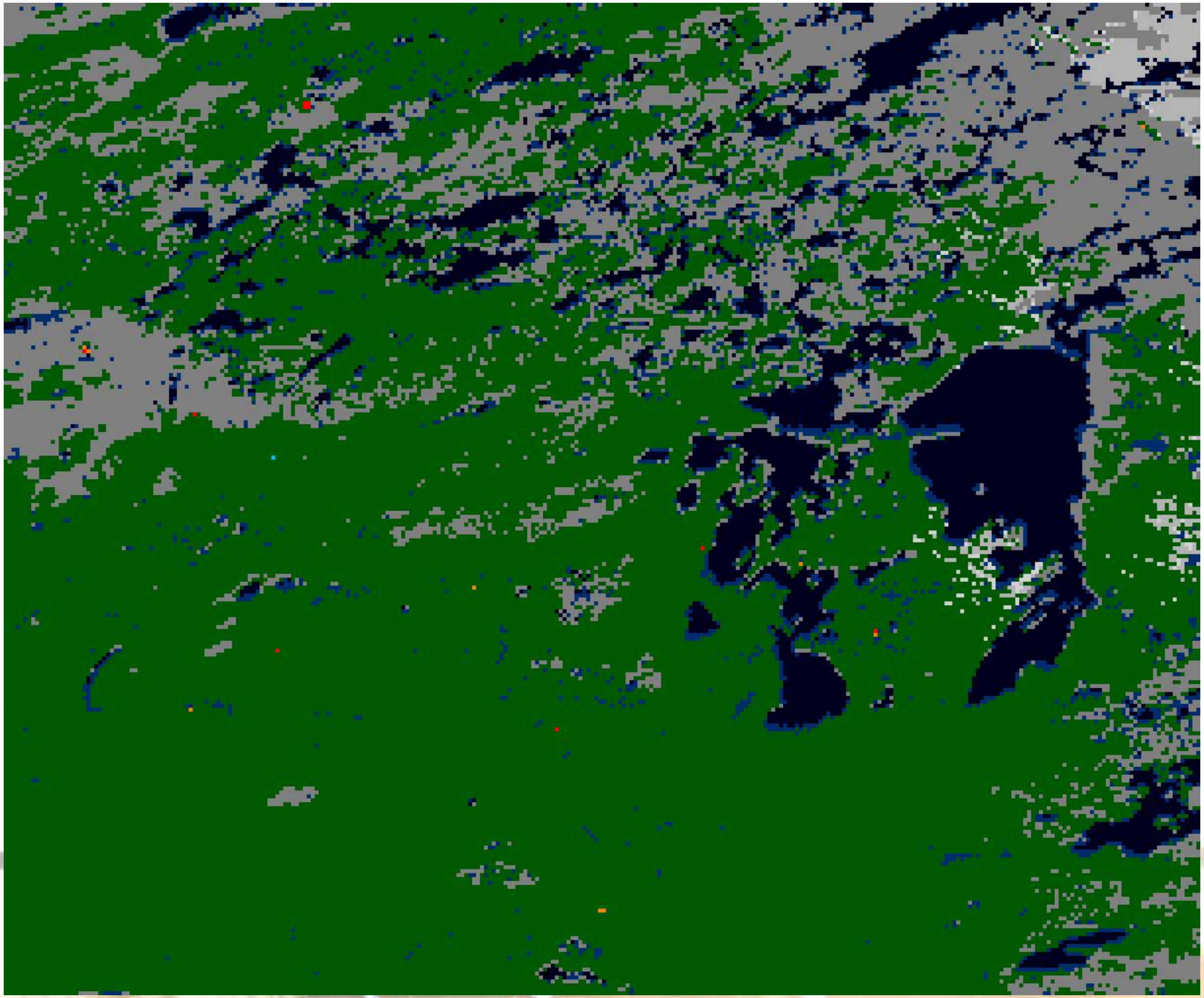
20 May 2018

Fire product mask

20:00:42 UTC

to

23:45:42 UTC



Fire Legend

- Processed Fire
- High Possibility Fire
- Saturated Fire
- Medium Possibility Fire
- Cloudy Fire
- Low Possibility Fire
- Fire-free ground
- Cold surface or cloud
- Cloudy (Rad Diff, night)
- Cloudy (Rad Diff, day)
- Background Calc Failed
- Water

Manitoba and Saskatchewan: 20 May 2018

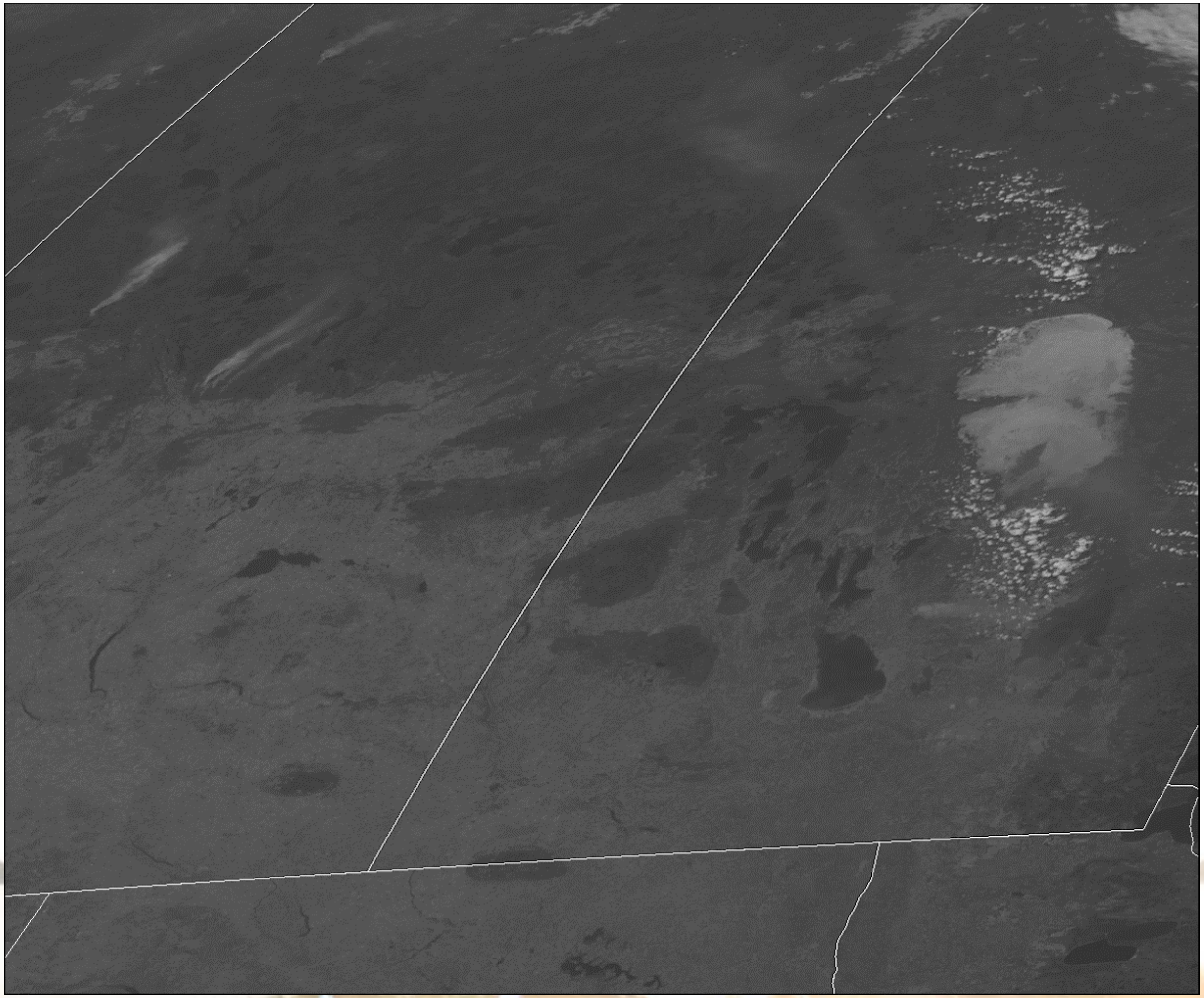
20 May 2018

Band 2, 0.64 μm

20:00:42 UTC

to

23:45:42 UTC



Manitoba and Saskatchewan: 20 May 2018

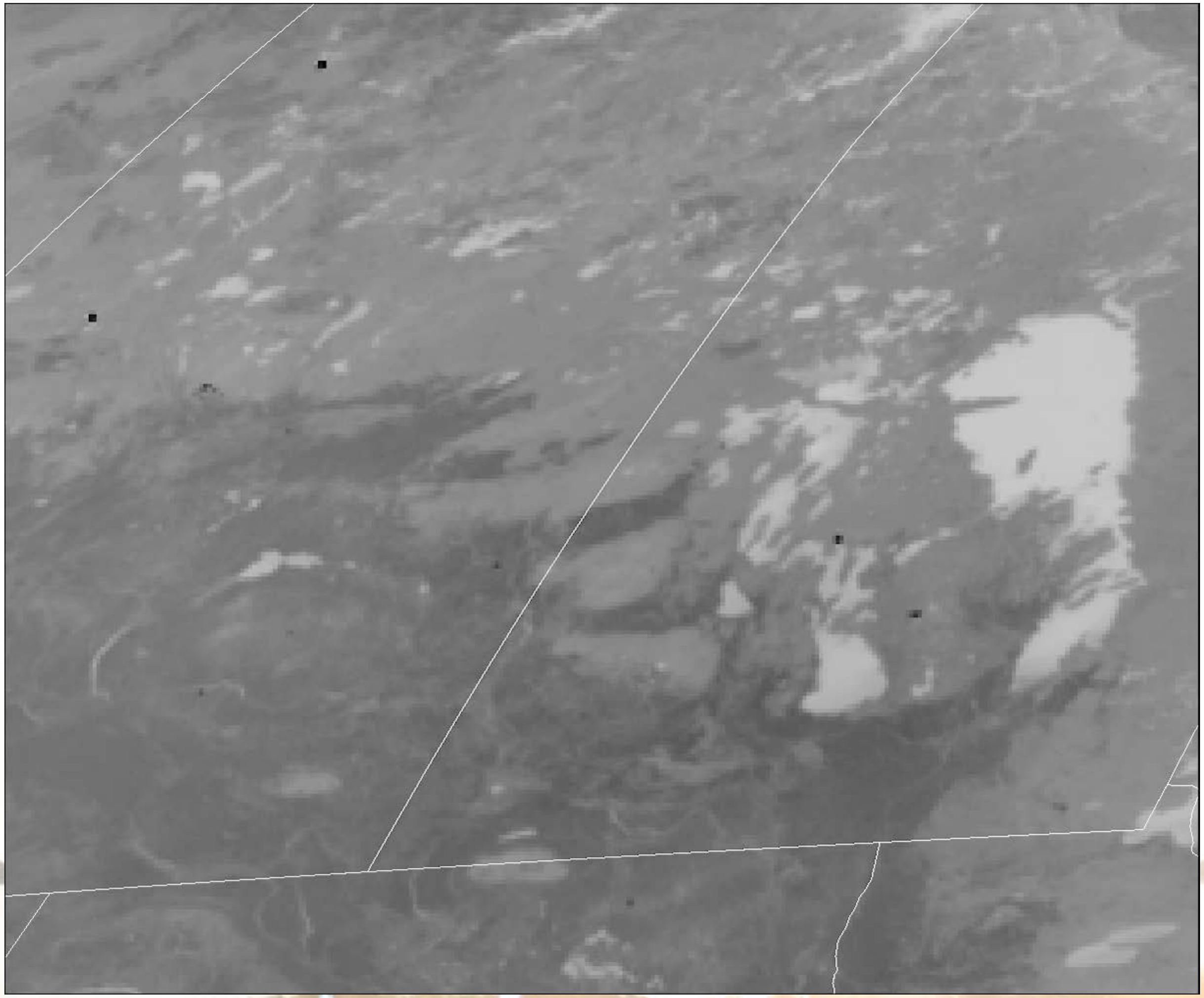
20 May 2018

Band 7, 3.9 μm

20:00:42 UTC

to

23:45:42 UTC



Manitoba and Saskatchewan: 20 May 2018

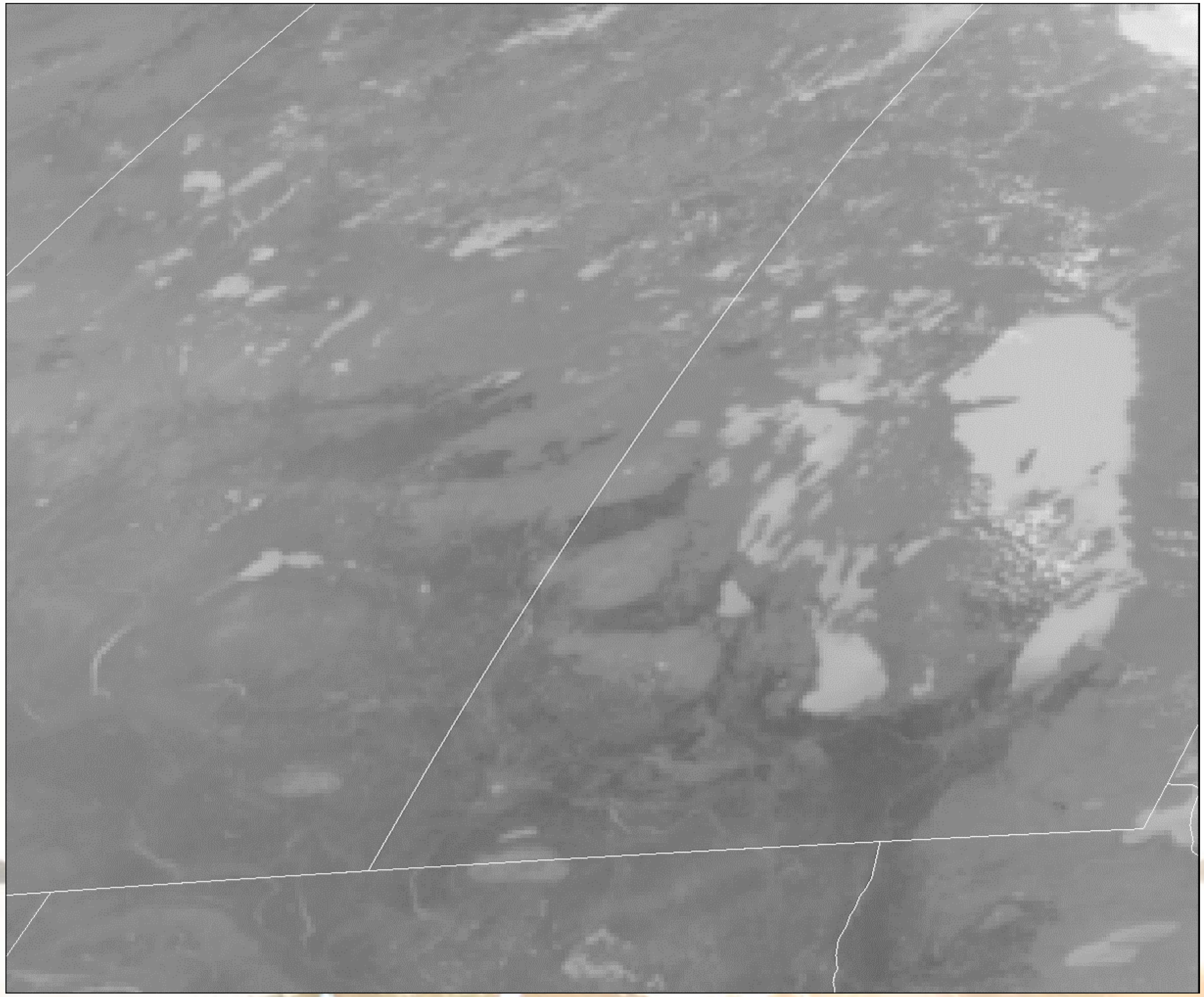
20 May 2018

Band 14, 11.2 μm

20:00:42 UTC

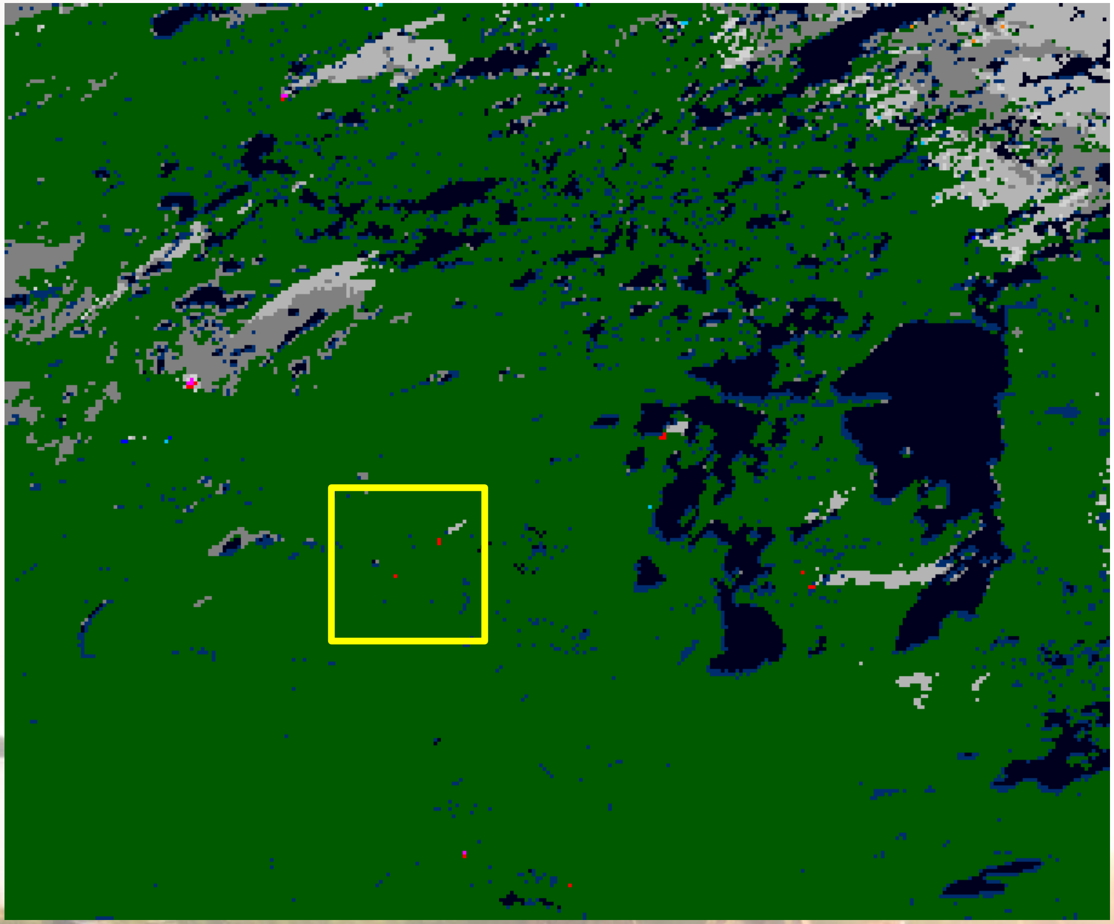
to

23:45:42 UTC



Closer Look Near Yorkton, Saskatchewan

Taking a closer look at some of the fires north/northeast of Yorkton, Saskatchewan
(Below image is 23:45:43 UTC on 20 May 2018)



Closer Look Near Yorkton, Saskatchewan

Google Maps image of the region in question
Mostly agricultural, mixed woods and wetlands as well

Closer Look Near Yorkton, Saskatchewan

20 May 2018

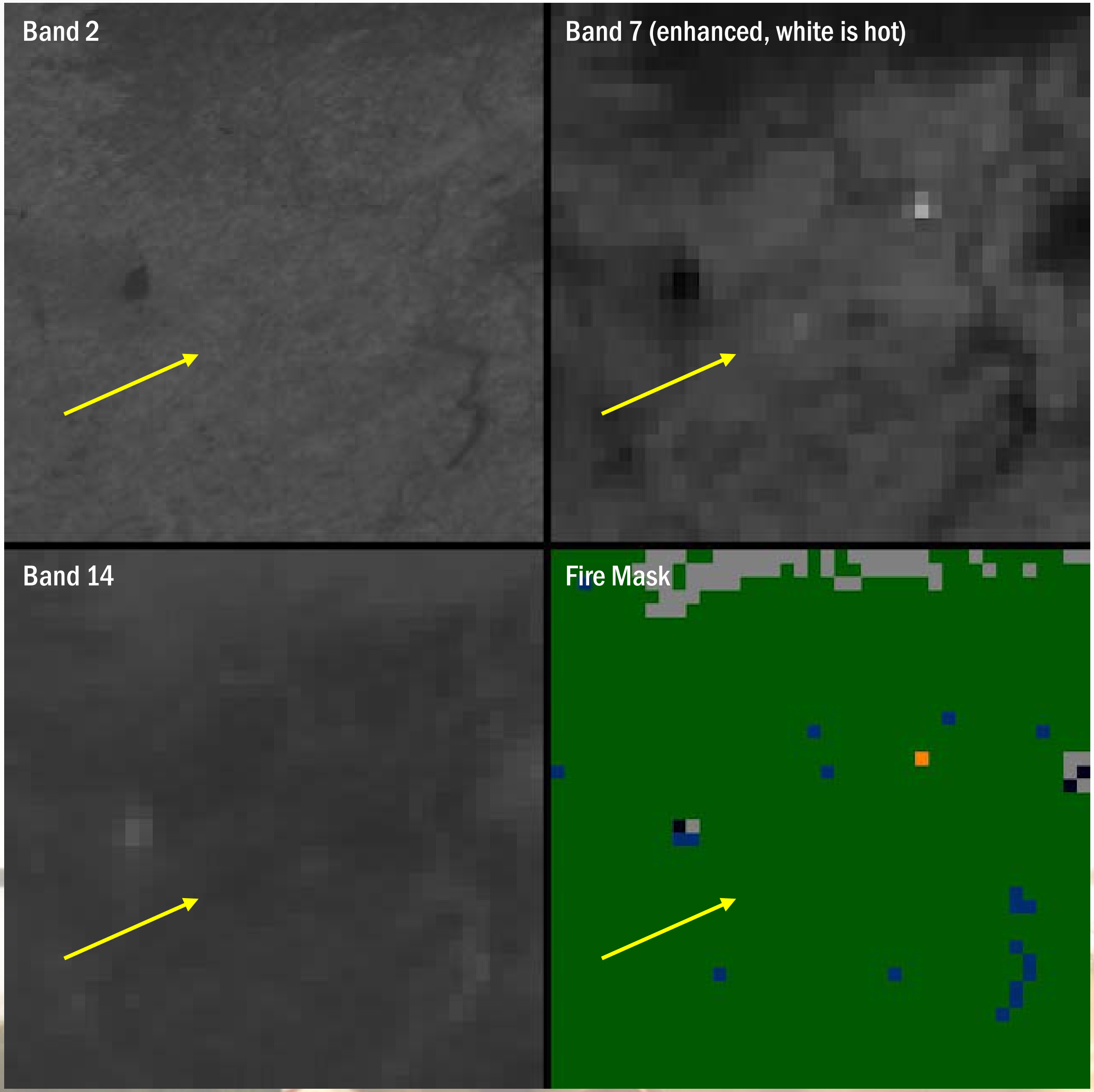
Fire product mask

20:00:42 UTC

to

23:45:42 UTC

Yellow arrow highlights a small fire at end of loop



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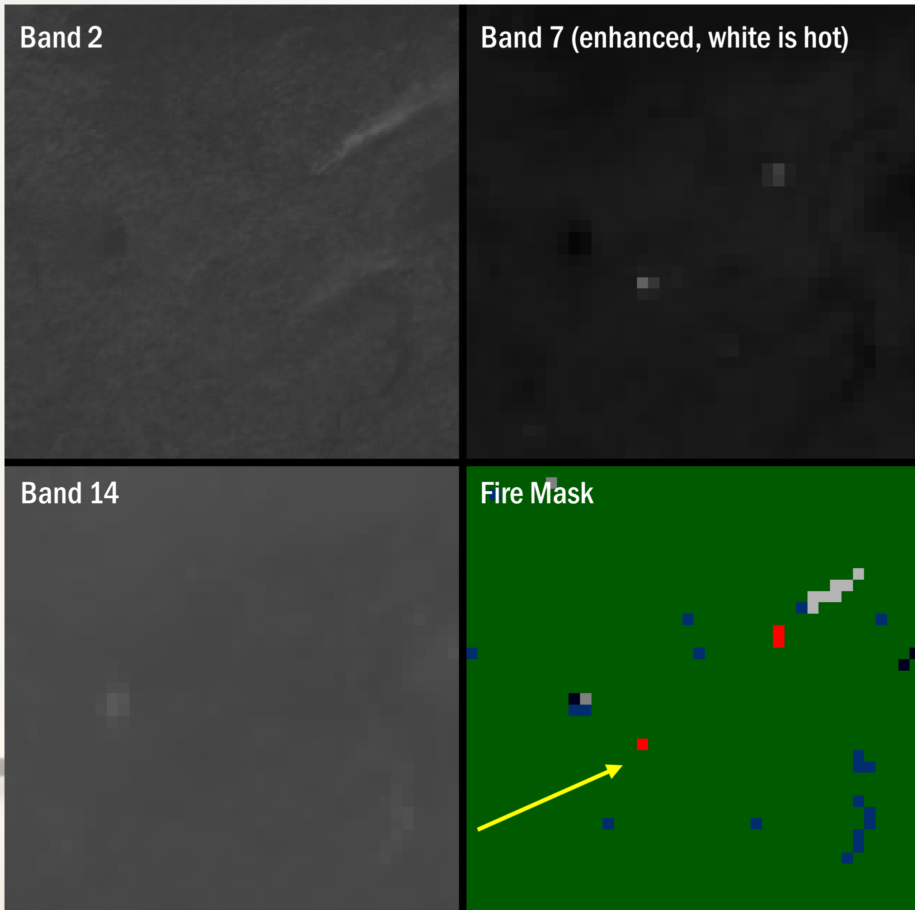
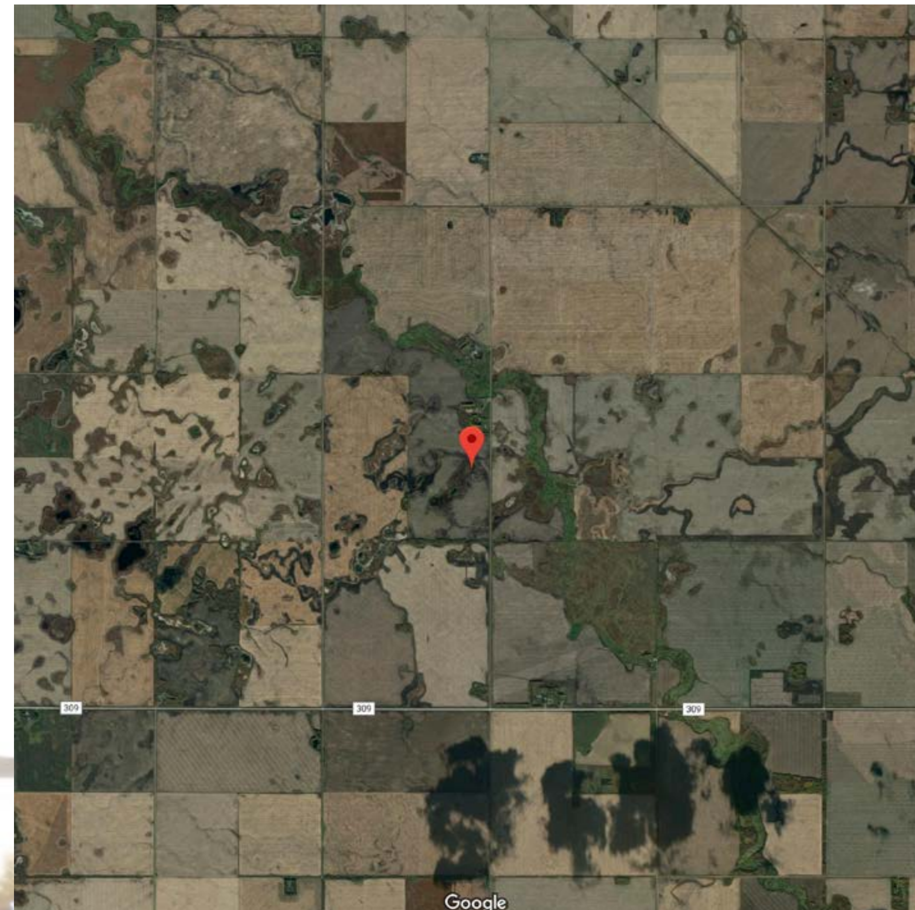
- Cloudy (Rad Diff, day)
- Background Calc Failed
- Water

Closer Look Near Yorkton, Saskatchewan

The small highlighted fire seen at 23:45:43 UTC on 20 May 2018 falls roughly within the scene to the right. Given the lack of visible oil facilities and presence of wetlands and agriculture, odds are this was a controlled burn or some sort of clearing in preparation for planting.





“Fire temperature RGB”

Red-green-blue combinations are popular among operational meteorologists, allowing rapid interpretation of scenes to pick out features. The “fire temperature RGB”, a combination of ABI bands 5, 6, and 7 (1.6, 2.2, and 3.9 μm, respectively), is particularly popular for being visually pleasing and allowing quick identification of larger hotspots. Like any tool, it has its benefits and drawbacks.

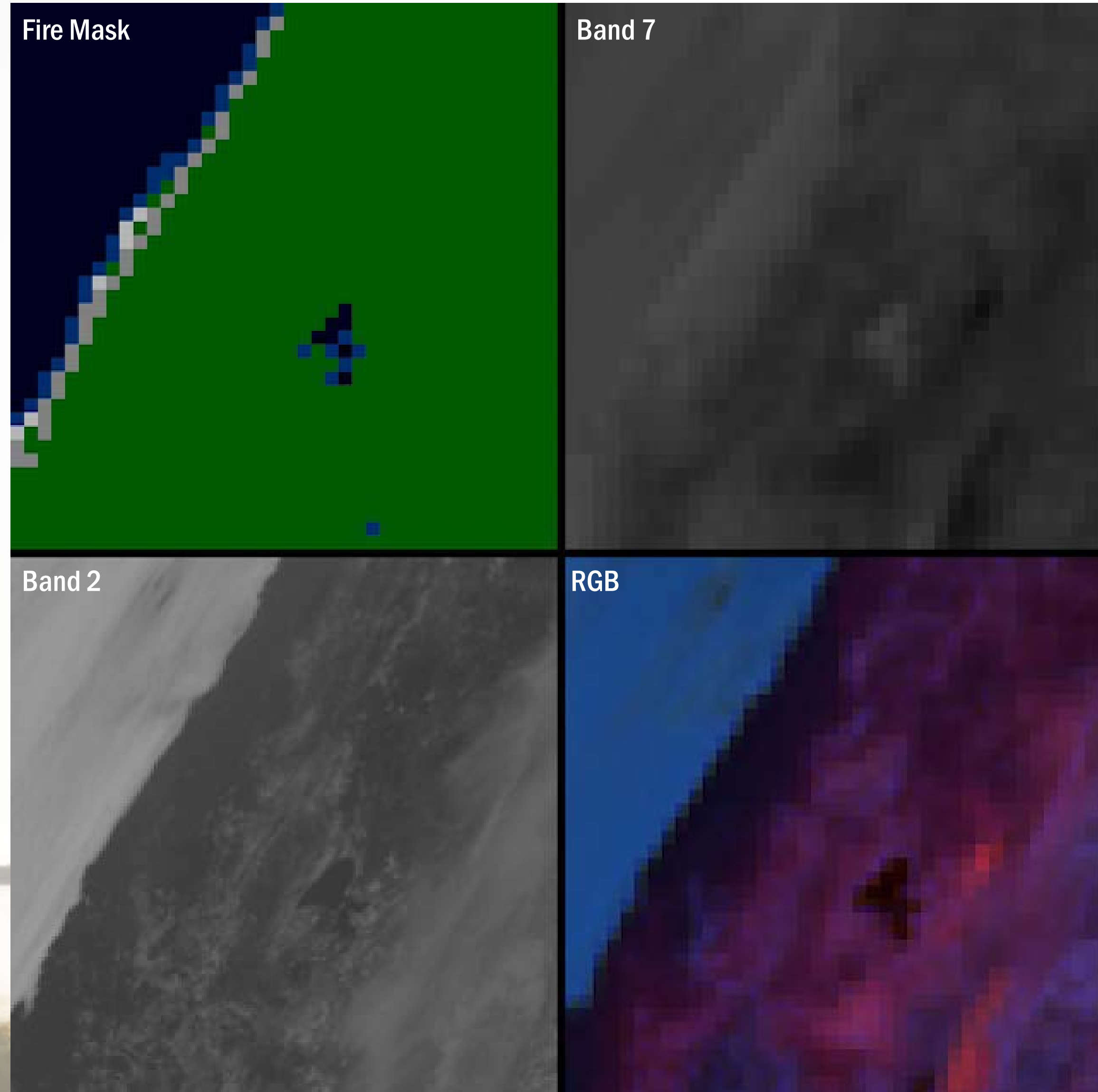
The first 5 hours of the Mendicino Complex fires (27 July 2018) will be used to illustrate the tool. The recorded start time of the Ranch Fire (northern fire of the two) was 12:03 PM PDT (19:03 UTC), and 1:01 PM PDT (20:01 UTC) for the River Fire (southern fire).

“Fire temperature RGB”

Mendicino Complex, 27 July 2018 (2018208) between 18 and 24 UTC

Fire temperature RGB captures this event, but without the image sequence fires can look identical to hot ground.

The fires were not visible in ABI imagery until about an hour after their reported start times.



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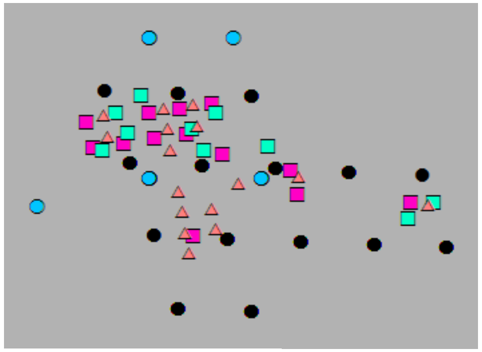
- Cloudy (Rad Diff, night)
- Cloudy (Rad Diff, day)
- Background Calc Failed
- Water

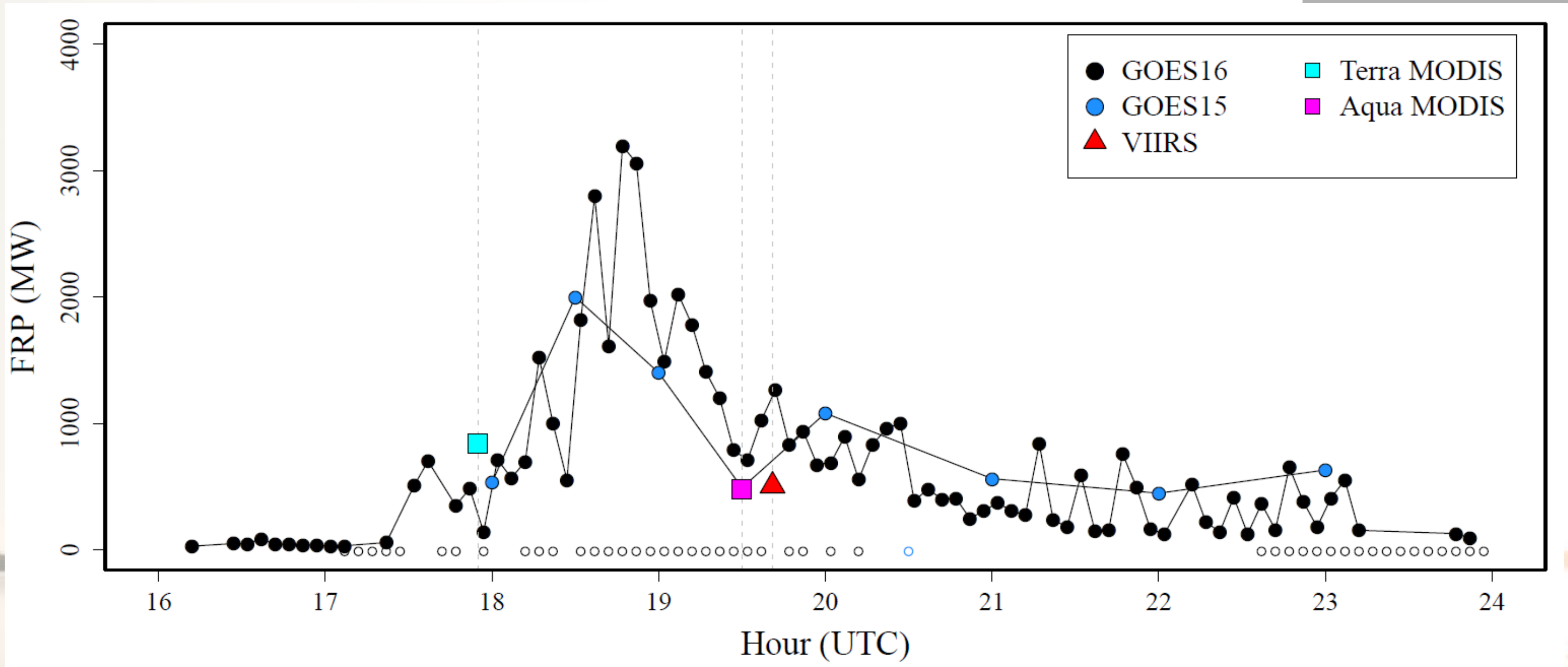
ABI fire products in Smoke and Aerosol Monitoring

- A handful of teams are using the GOES-16 Fire Radiative Power (FRP) product to produce smoke forecasts
- FRP agreement was good with polar orbiting platforms and the data produced a helpful diurnal signature
- Results from these studies will be presented by those teams at upcoming meetings

FRP Comparison Between Platforms

FRP time series on 24 March 2018, northwest of Tulsa, OK – results are comparable between all platforms

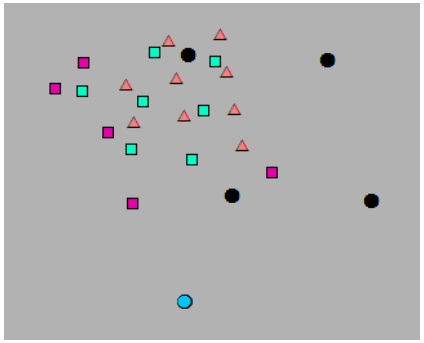


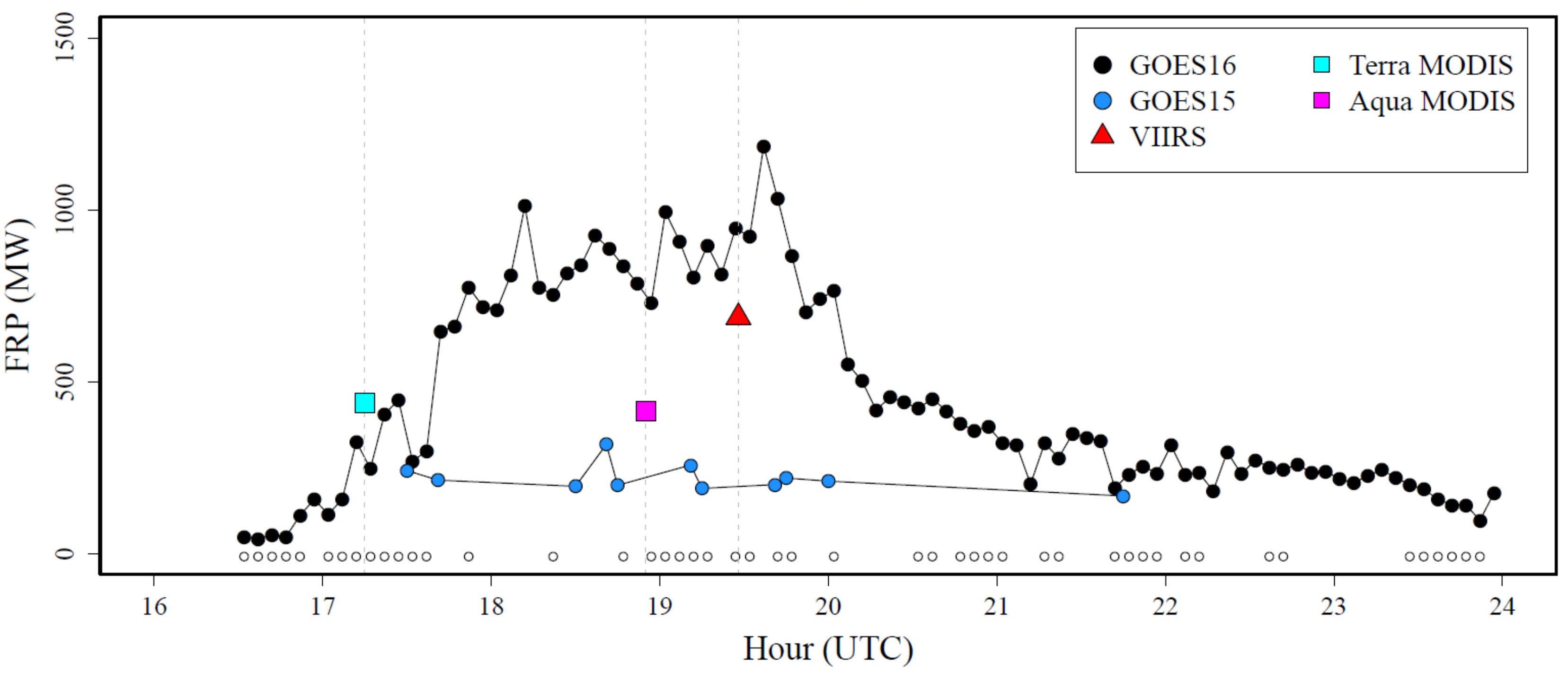


Plots and images courtesy Dr Wilfrid Schroeder and Joanne Hall

FRP Comparison Between Platforms

FRP time series on 14 March 2018, east of Tulsa, OK – results are comparable between all platforms except for GOES-15. Why?



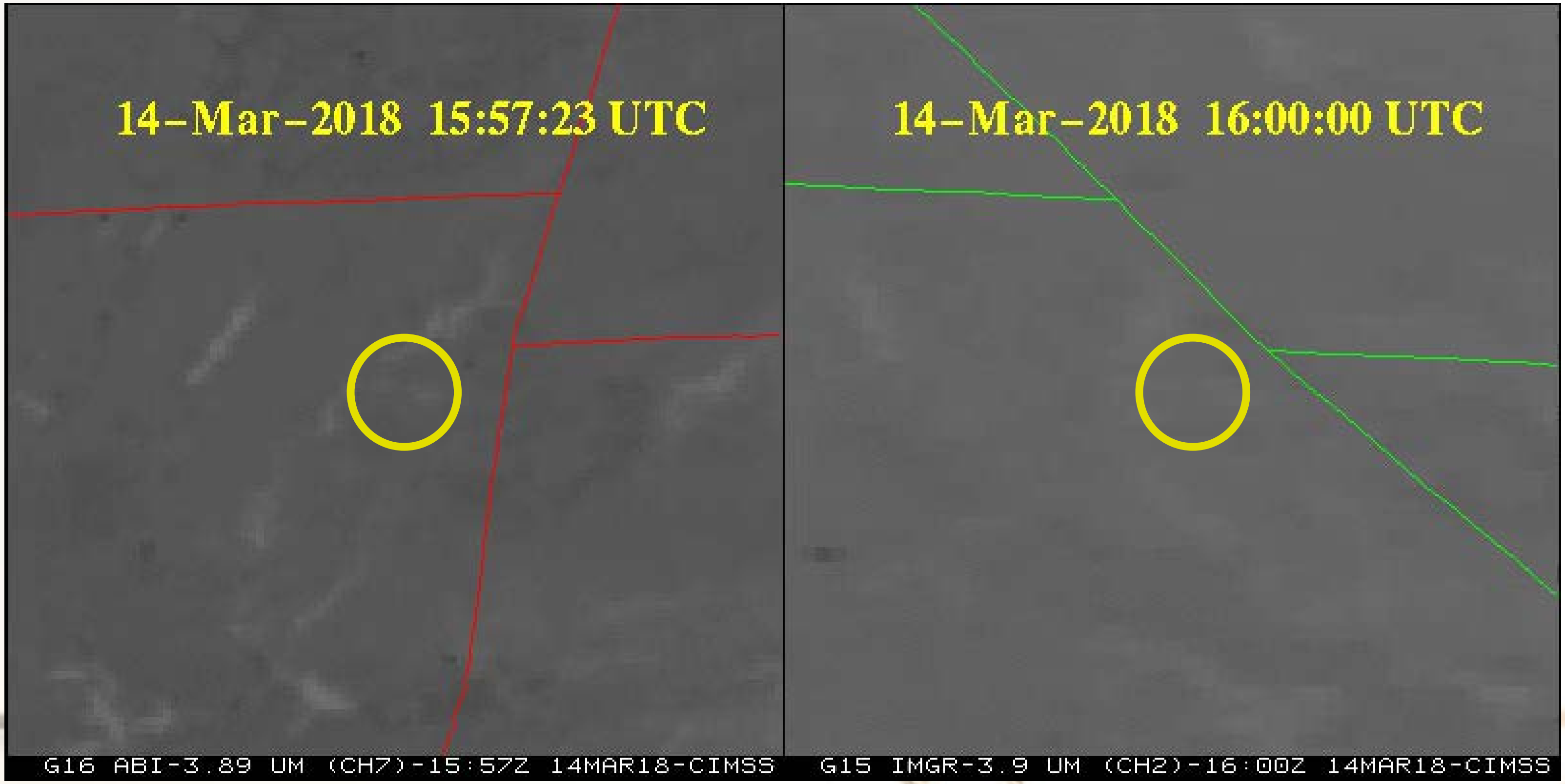


Notably poor agreement between G16 and G15 - Why?

Plots and images courtesy Dr Wilfrid Schroeder and Joanne Hall

FRP Comparison Between Platforms

3.9µm data, GOES-16 on the left, GOES-15 on the right
The fire in question (inside the yellow circles) looks very different – why?

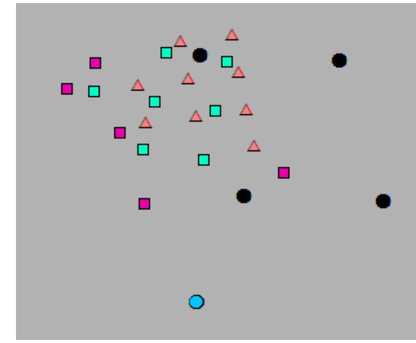


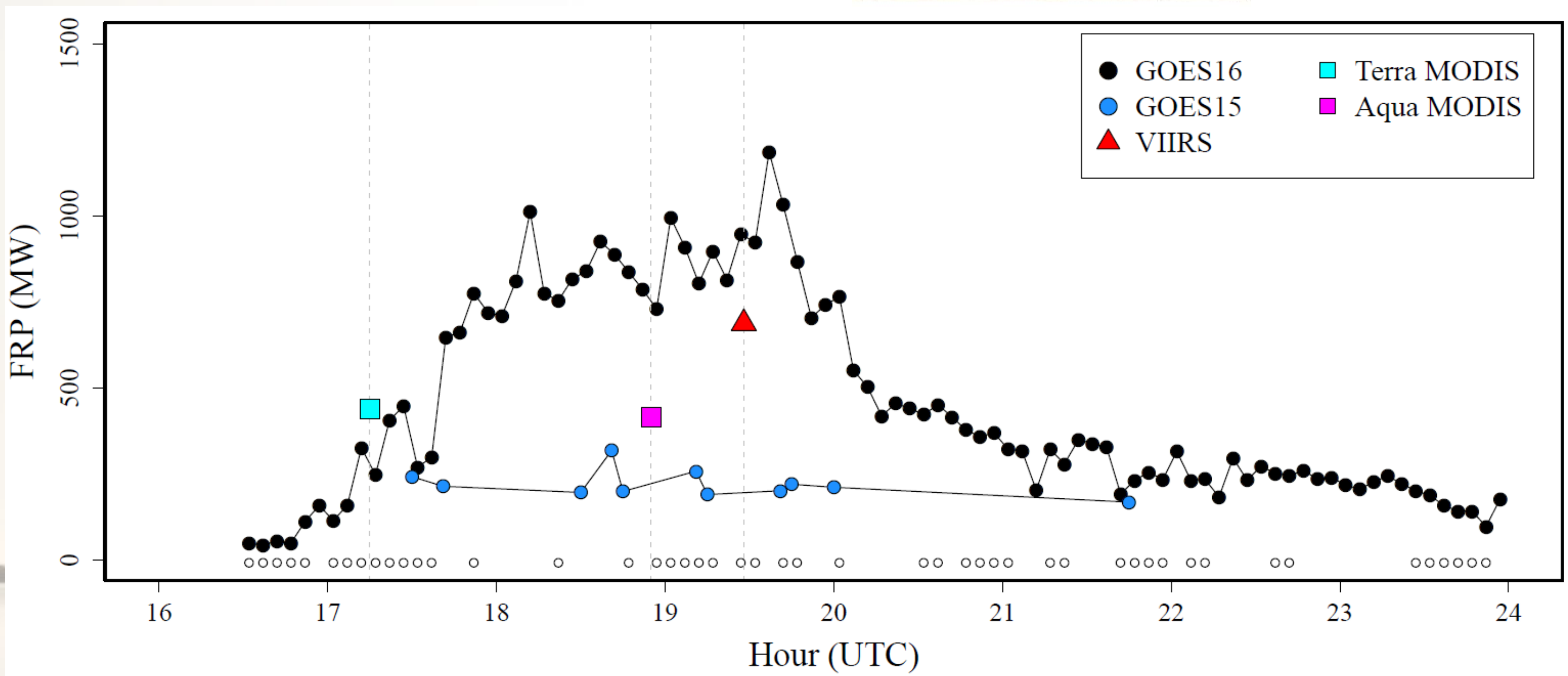
FRP Comparison Between Platforms

The answer is terrain: this fire was on an eastern facing slope, affording GOES-16 (and some of the polar orbiters) good viewing angles while GOES-15 had a bad one.

FRP Comparison Between Platforms

The effects of terrain and viewing geometry are notable, and must be considered when comparing platforms and assessing whether a satellite could have seen a given fire.





Plots and images courtesy Dr Wilfrid Schroeder and Joanne Hall

FDCA Current Status

- Currently considered Provisional, however users who have a high sensitivity to false alarms and/or composite multiple time periods have reported false alarm problems during the Northern Hemisphere's summer
- An update will soon be implemented that decreases the algorithm's sensitivity and makes other changes that substantially reduce the false alarm rate but will also remove some legitimate fires
- Users who track specific fire incidents have reported fewer problems

FDCA data availability

- Provisional FDCA GOES-16 L2 data is available now
- GOES-17 FDCA is not yet available
- Currently will be produced from the Ground System (GS) for Full Disk (FD) and CONUS sectors
- It is **not** produced by the GS for MESO sectors
- Fire weather is in the priority list for calling MESO sectors

Questions?

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Just how sensitive is ABI to fire?

MESO scans

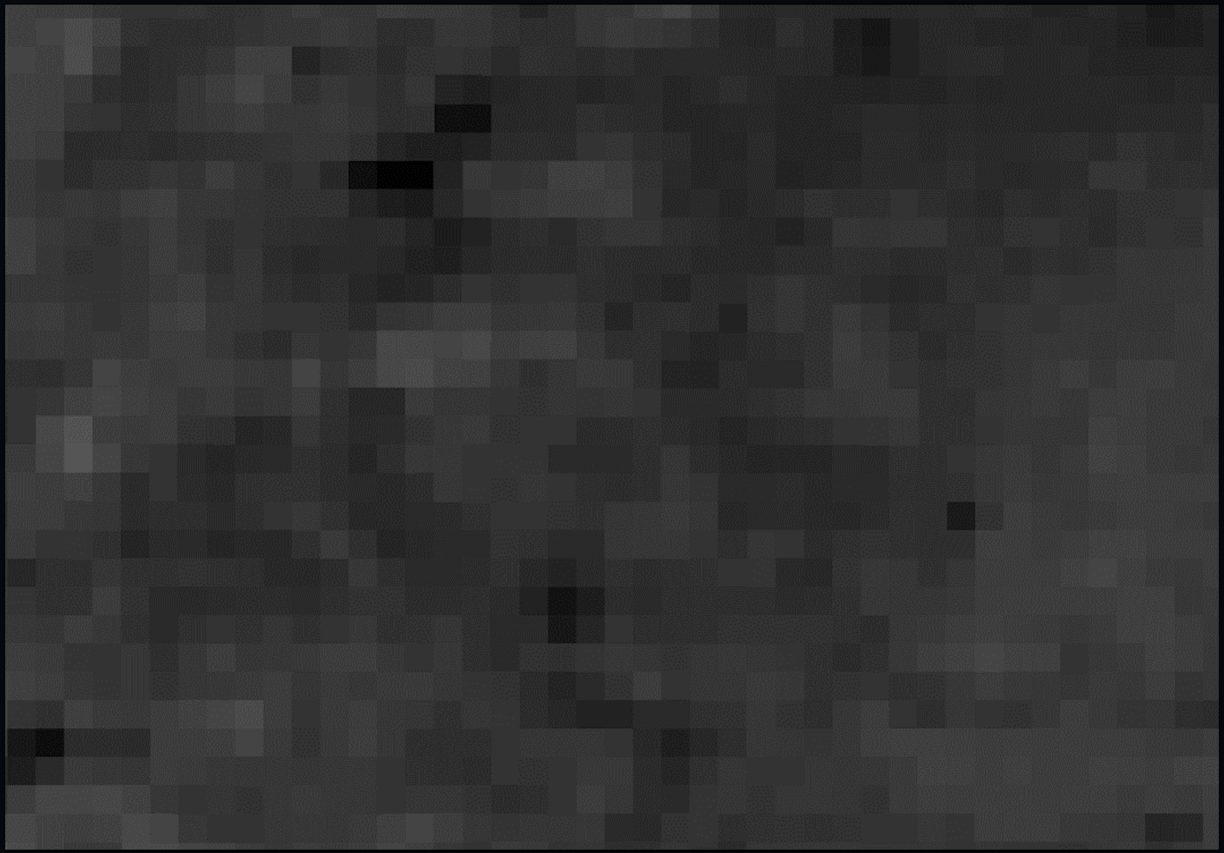
- Data captured over a region every minute
- While the FDCA is not produced for the MESO scans, NWS forecasters in Norman, OK are relying on it heavily for early fire detection and alerting local emergency services when they see something of concern
- The one minute cadence does reveal events that would escape detection at 5 minute or longer time steps

Remapping

- Due to remapping the fire signal “spills” into neighboring pixels
- It turns out that this can be seen for almost any fire (may require enhancements)
- Most fires show a signal in a 2x2 or larger block of pixels
- The FDCA does not exploit this (yet), but by design it ignores the pixels immediately surrounding the one being analyzed

Just how sensitive is ABI to fire?

Oklahoma, 6 March 2018, 16:30-16:59 MESO1 scan

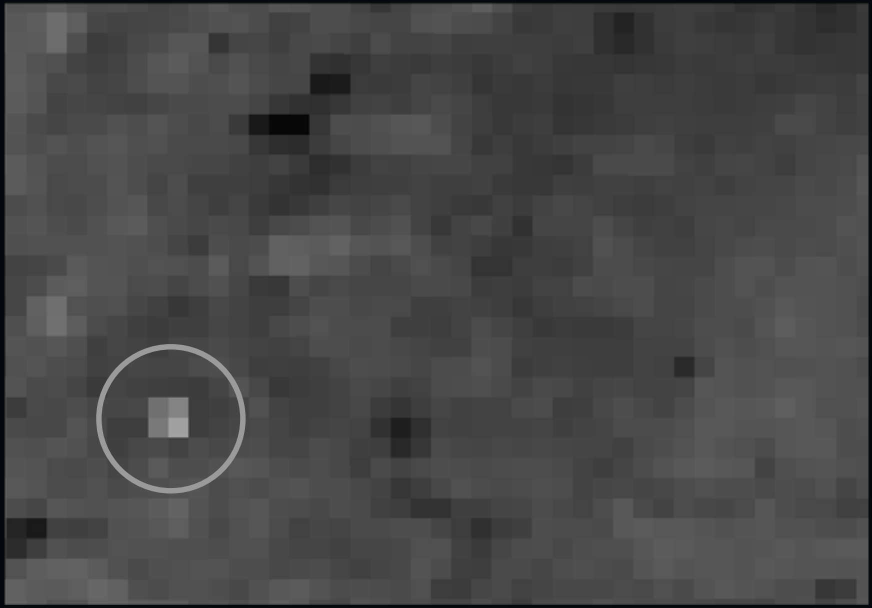


Stretched from 291K to 306K, white is warmer

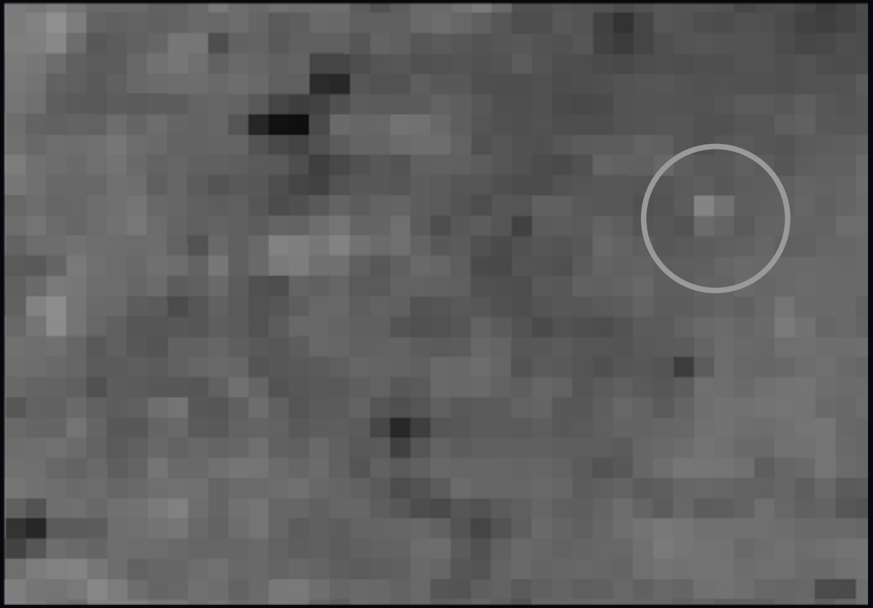
Just how sensitive is ABI to fire?

Oklahoma, 6 March 2018, 16:30-16:59 MESO1 scan

Two fires are visible, a larger one in the lower left that barely reaches the minimum threshold for quantitative detection, and the structure fire on the upper right which exceeds background by ~ 1 K.



16:42:22 UTC



16:50:22 UTC

Just how sensitive is ABI to fire?

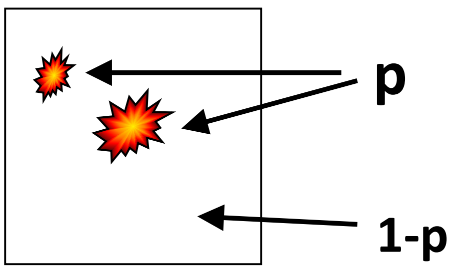
Oklahoma, 6 March 2018, 16:30-16:59 MESO1 scan

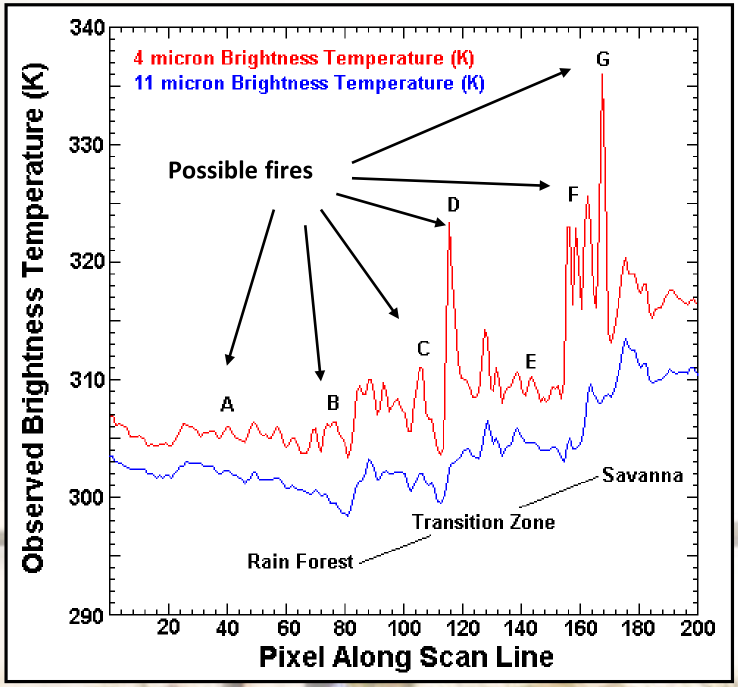
- Neither fire would have been captured by the quantitative algorithm due to magnitude and timing
- Either fire could have ignited a larger one under the right conditions
- Human monitoring is important, but catching something like these fires is hard
- During the 30 minute loop the entire scene warmed more than either fire raised pixel temperatures
- The difference between 4 and 11 µm brightness temperatures grew for the entire scene; warming in band 7 was due to solar reflection; fixed-threshold "RGB" imagery is not well suited for these cases

Fire Detection and Characterization

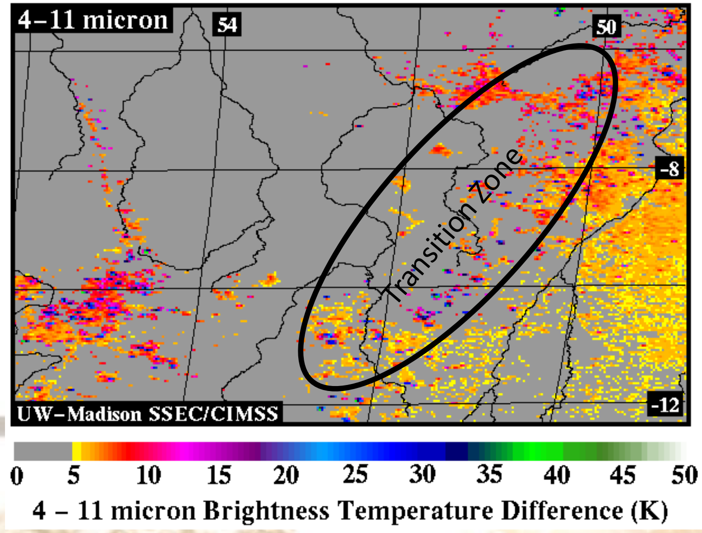
Typically, the difference in brightness temperatures between the two infrared windows is due to ***reflected solar radiation***, ***surface emissivity*** differences, and ***water vapor attenuation***. At night this normally results in brightness temperature differences of 2-4 K, though it is higher during the day (20 K or more!).

Larger differences occur when one part of a pixel (p) is substantially warmer than the rest of the pixel (1-p). The hotter portion will contribute more radiance (energy) in shorter wavelengths than in the longer wavelengths.



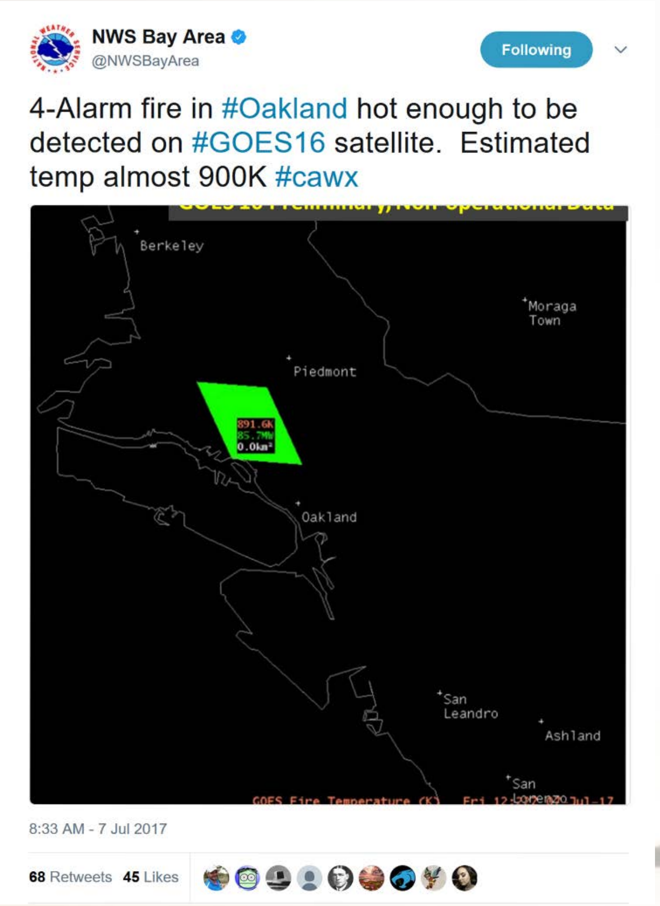


Brightness temperatures along a scan line in NE Brazil



NE Brazil along the transition zone between forest and savanna

Fire Detection and Characterization


NWS Bay Area
@NWSBayArea
Following

4-Alarm fire in #Oakland hot enough to be detected on #GOES16 satellite. Estimated temp almost 900K #cawx

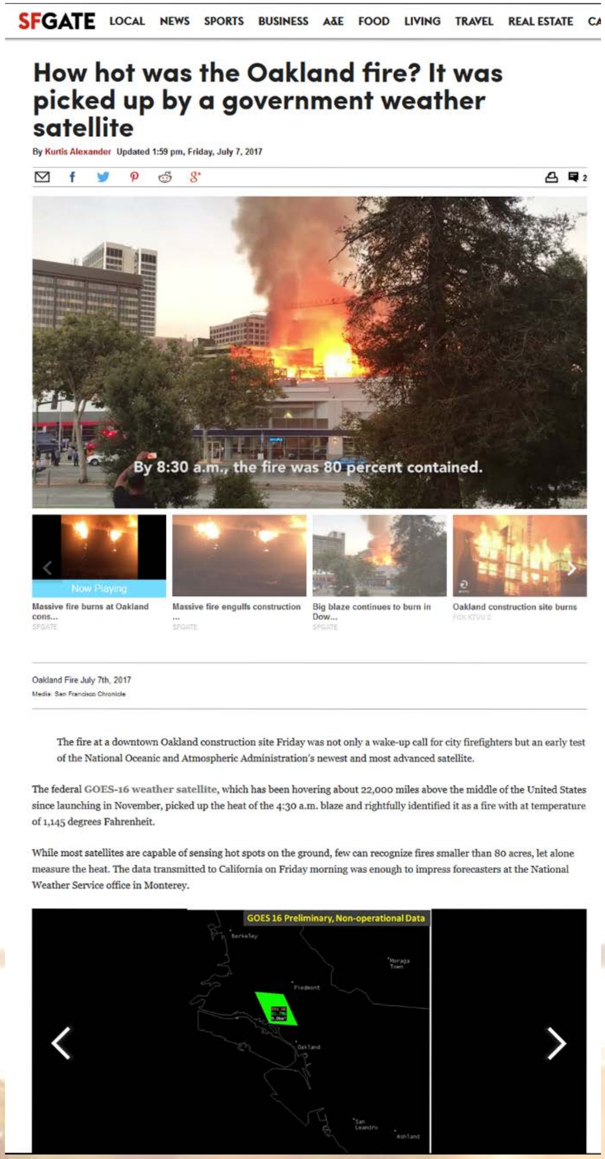
8:33 AM - 7 Jul 2017

68 Retweets 45 Likes

The GOES-16 detection received some press coverage

Bay Area NWS
tweet at left:
https://twitter.com/NWSBayArea/status/883318084525752320

SFGate at right:
http://www.sfgate.com/bayarea/article/How-hot-was-the-Oakland-fire-It-was-picked-up-by-11273203.php


SFGATE LOCAL NEWS SPORTS BUSINESS A&E FOOD LIVING TRAVEL REAL ESTATE

How hot was the Oakland fire? It was picked up by a government weather satellite

By Kurtis Alexander Updated 1:59 pm, Friday, July 7, 2017

Oakland Fire July 7th, 2017
Media: San Francisco Chronicle

The fire at a downtown Oakland construction site Friday was not only a wake-up call for city firefighters but an early test of the National Oceanic and Atmospheric Administration's newest and most advanced satellite.

The federal GOES-16 weather satellite, which has been hovering about 22,000 miles above the middle of the United States since launching in November, picked up the heat of the 4:30 a.m. blaze and rightfully identified it as a fire with at temperature of 1,145 degrees Fahrenheit.

While most satellites are capable of sensing hot spots on the ground, few can recognize fires smaller than 80 acres, let alone measure the heat. The data transmitted to California on Friday morning was enough to impress forecasters at the National Weather Service office in Monterey.